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GATE 2018

Electrical Engineering

(Afternoon Session - 10.02.2018)

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GATE EE ANALYSIS -2018, 10th Feb Afternoon

Subject	Number of Questions		Total Marks
General Aptitude	1 Mark : 5 2 Marks : 5	Total Questions (10)	15
Engineering Mathematics	1 Mark : 4 2 Marks : 4	Total Questions (8)	12
Network Theory	1 Mark : 2 2 Marks : 5	Total Questions (7)	12
Electrical Machines	1 Mark : 3 2 Marks : 4	Total Questions (7)	11
Power Systems	1 Mark : 5 2 Marks : 3	Total Questions (8)	11
Power Electronics	1 Mark : 3 2 Marks : 3	Total Questions (6)	9
Control Systems	1 Mark : 2 2 Marks : 3	Total Questions (5)	8
Signals & Systems	1 Mark : 2 2 Marks : 3	Total Questions (5)	8
Digital Electronics	1 Mark : 1 2 Marks : 2	Total Questions (3)	5
Analog Electronics	1 Mark : 1 2 Marks : 1	Total Questions (2)	3
Electro Magnetic Field	1 Mark : 1 2 Marks : 1	Total Questions (2)	3
Electrical & Electronics Measurement	1 Mark : 1 2 Marks : 1	Total Questions (2)	3
Total	1 Mark : 30 2 Marks : 35	65	100

GATE 2018 [Afternoon Session]
Electrical Engineering

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General Aptitude

Q.1 to Q.5 carry one mark each

Question 1

For what values of k given below is $\frac{(k+2)^2}{k-3}$ an integer?

(A) 4, 8, 18 (B) 4, 10, 16 (C) 4, 8, 28 (D) 8, 26, 28

Ans. **(C)**

Sol. Given : $f(k)=\frac{(k+2)^2}{k-3}$

Going by options

when $k=4,\ f(k)=36$, which is integer

when $k=8,\ f(k)=20$, which is integer

when $k=28,\ f(k)=36$, which is integer

Hence, the correct option is (C).

Question 2

"Since you have gone off the _____ the _____ sand is likely to damage the car". The words that best fill the blanks in the above sentence are

(A) course, coarse (B) course, course (C) coarse, course (D) coarse, coarse

Ans. **(A)**

Question 3

"A common misconception among writers is that sentence structure mirrors thought, the more _____ the structure, the more complicated the ideas."

The words that best fill the blanks in the above sentence are

(A) detailed (B) simple (C) clear (D) convoluted

Ans. **(D)**

Question 4

Functions $F(a, b)$ and $G(a, b)$ are defined as follows :

$F(a, b)=(a-b)^2$ and $G(a, b)=|a-b|$, where $|x|$ represents the absolute value of x.

What would be the value of $G(F(1, 3), G(1, 3))$?

(A) 2 (B) 4 (C) 6 (D) 36

Ans. **(A)**

Sol. **Given :** $f(a,b)=(a-b)^2$

$g(a,b)=|a-b|$

So, $f(1, 3)=(1-3)^2=4$

$g(1, 3)=|1-3|=2$

$g[f(1, 3), g(1, 3)]=g(4, 2)=|4-2|$

$g[f(1, 3), g(1, 3)]=2$

Hence, the correct option is (A).

More questions and video solutions of GATE - 2018 are available in the Facebook group "GATE ACADEMY (EE/EC/IN)". To join click here https://www.facebook.com/groups/gateconcepts/

Question 5

The three roots of the equation $f(x)=0$ are $x=\{-2, 0, 3\}$. What are the three values of x for which $f(x-3)=0$?

(A) $-5, -3, 0$ (B) $-2, 0, 3$ (C) $0, 6, 8$ (D) $1, 3, 6$

Ans. **(D)**

Sol. **Given :** $f(x)=0$ for $x=(-2, 0, 3)$

$$f(x)=(x+2)x(x-3)=0$$

$$f(x-3)=(x-3+2)(x-3)(x-3-3)=0$$

$$x=1, 3, 6$$

Hence, the correct option is (D).

Q.6 to Q.10 carry two marks each

Question 6

An e-mail password must contain three characters. The password has to contain one numeral from 0 to 9, one upper and one lower case character from the English alphabet. How many distinct passwords are possible?

(A) 6,760 (B) 13,520 (C) 40,560 (D) 1,05,456

Ans. **(C)**

Sol. Number of different passwords $= 26C_1 \times 26C_1 \times 3! = 40560$.

Hence, the correct option is (C).

Question 7

In a certain code, AMCF is written as EQGJ and NKUF is written as ROYJ. How will DHLP be written in that code?

(A) RSTN (B) TLPH (C) HLPT (D) XSVR

Ans. **(C)**

Sol.

BCD → E, NOP → Q, DEF → G, GHI → J

OPQ → R, LMN → O, VWX → Y, GHI → J

EFG → H, IJK → L, MNO → P, QRS → T

Hence, the correct option is (C).

Question 8

A class of twelve children has two more boys than girls. A group of three children are randomly picked from this class to accompany the teacher on a field trip. What is the probability that the group accompanying the teacher contains more girls than boys?

(A) 0 (B) $\frac{325}{864}$ (C) $\frac{525}{864}$ (D) $\frac{5}{12}$

Ans. **(*) 4/11**

Sol. **Given :**

Total children = 12

Here boys are two more than girls hence,

Boy (B) = 7 and Girl (G) = 5

Now three children are randomly picked. Hence,

Total combination for that, $N = {}^{12}C_3 = 220$

Now in the group, if girls are more than boys, then we have possible combinations :

(i) 2 Girls, 1 Boy $\rightarrow$ $N_1 = {}^5C_2 \times {}^7C_1 = 70$

(ii) 3 Girls, 0 Boy $\rightarrow$ $N_2 = {}^5C_3 \times {}^7C_0 = 10$

Hence, the probability $(P) = \frac{N_1 + N_2}{N} = \frac{70+10}{220} = \frac{4}{11}$

Hence, the given options are not correct. The right answer for this question is $\mathbf{\frac{4}{11}}$.

Question 9

P, Q, R and S crossed a lake in a boat that can hold a maximum of two persons, with only one set of oars. The following additional facts are available.

(i) The boat held two persons on each of the three forward trips across the lake and one person on each of the two return trips.

(ii) P is unable to row when someone else is in the boat.

(iii) Q is unable to row with anyone else except R.

(iv) Each person rowed for at least one trip

(v) Only one person can row during a trip

Who rowed twice?

(A) P (B) Q (C) R (D) S

Ans. **(C)**

Sol. P has to row on return journey as he can not row with anyone else. On next trip P will be leaving R and R will row. After this R will return back to pickup Q so on the last trip Q and R will go together in which Q will be rowing the boat.

Hence R will be rowing the boat twice.

Hence, the correct option is (C).

Question 10

A designer uses marbles of four different colours for his designs. The cost of each marble is the same, irrespective of the colour. The table below shows the percentage of marbles of each colour used in the current design. The cost of each marble increased by 25%. Therefore, the designer decided to reduce equal numbers of marbles of each colour to keep the total cost unchanged. What is the percentage of blue marbles in the new design?

Blue	Black	Red	Yellow
40%	25%	20%	15%

(A) 35.75 (B) 40.25 (C) 43.75 (D) 46.25

Ans. **(C)**

Sol. Assume a total of 100 marbles each of cost 1 unit

Blue paper = 40

Black paper = 25

Red paper = 20

Yellow paper = 15

Let x marbles are reduced from each type & cost of each marble is 1.25

Total cost should remain 100

$$(40-x)1.25+(25-x)1.25+(20-x)1.25+(15-x)1.25=100$$

$$125-5x=100$$

$$x=5$$

Blue = 35

Black = 20

Red = 15

Yellow = 10

$$\%\ \text{Blue} = \frac{35}{80}\times 100 = 43.75\%$$

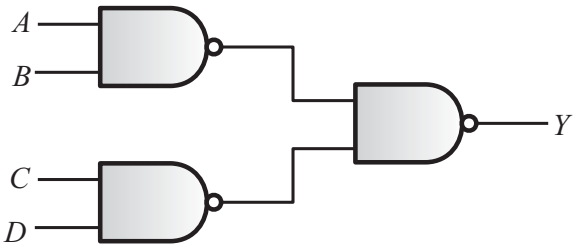
Hence, the correct option is (C).

Technical Part

Q.1 to Q.25 carry one mark each

Question 1 **(Digital Electronics)**

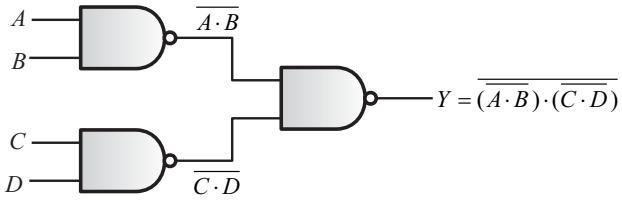
In the logic circuit shown in the figure, Y is given by



(A) $Y = ABCD$ (B) $Y = (A+B)(C+D)$ (C) $Y = A+B+C+D$ (D) $Y = AB+CD$

Ans. **(D)**

Sol. **Given :**



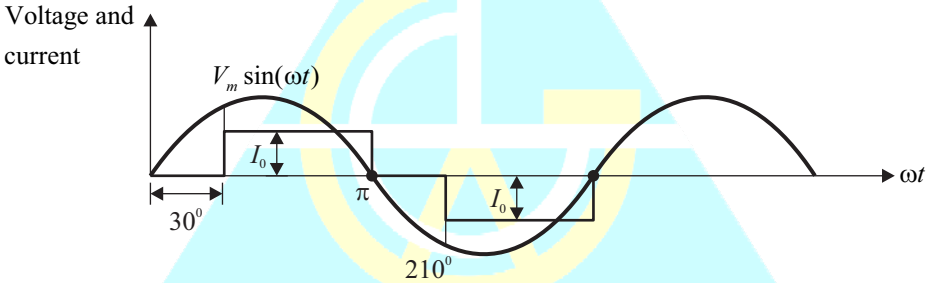
$$f = \overline{\overline{AB}\cdot\overline{CD}} = \overline{\overline{AB}} + \overline{\overline{CD}} = AB + CD$$

[By De-Morgan theorem $\overline{AB} = \bar{A} + \bar{B}$ and $\overline{A+B} = \bar{A}\,\bar{B}$]

Hence, the correct option is (D).

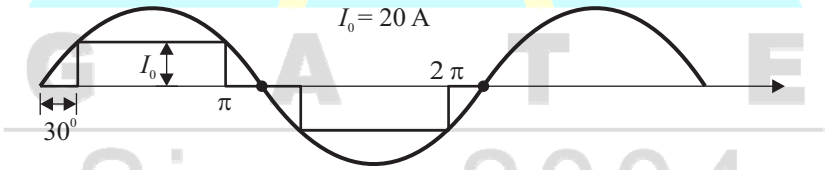
Question 2 (Power Electronics)

The waveform of the current drawn by a semi-converter from a sinusoidal AC voltage source is shown in the figure. If $I_0 = 20$ A, the rms value of fundamental component of the current is _____ A (up to 2 decimal places).

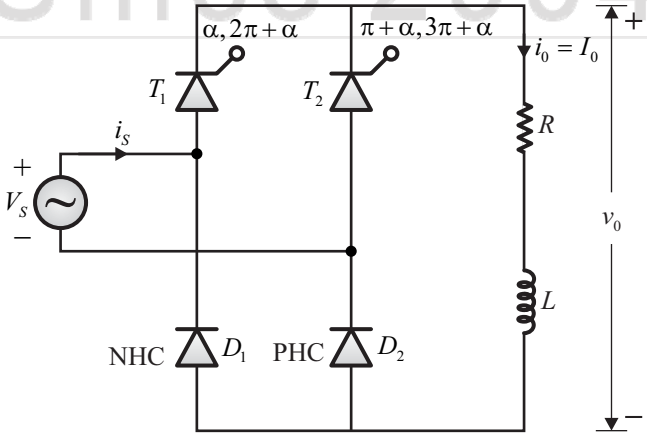


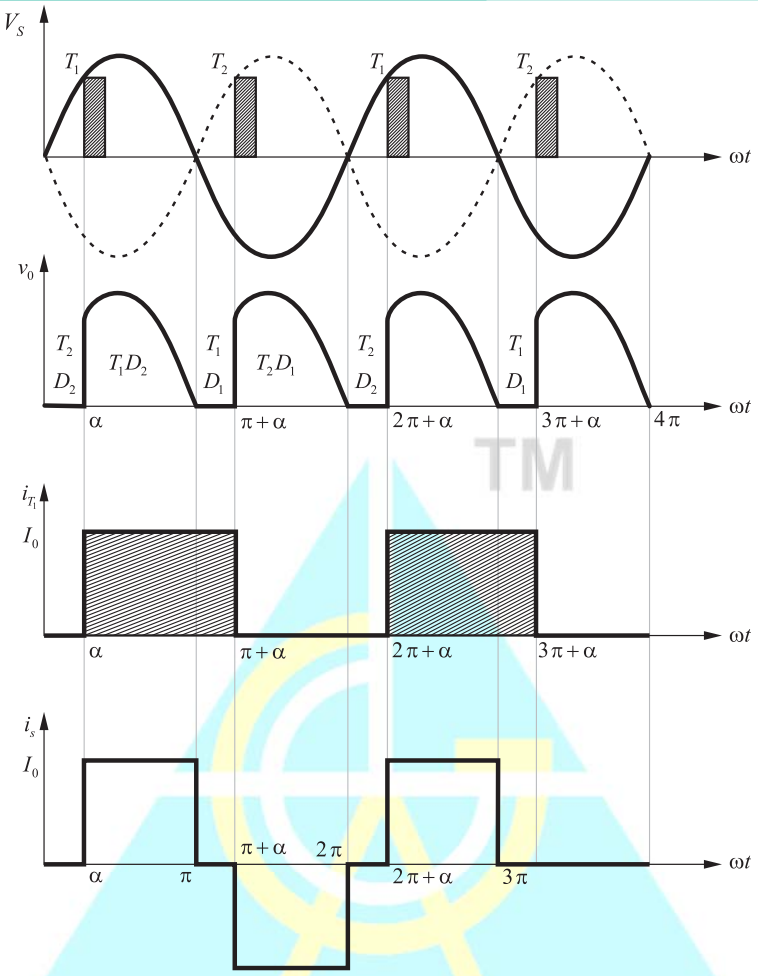
Ans. **17.39**

Sol. **Given :** Assuming single phase symmetrical semi-converter (we can also opt single phase asymmetrical semi-converter as the output voltage and current waveform of load and source will not be affected)



The given circuit is a symmetrical single phase semi-converter,

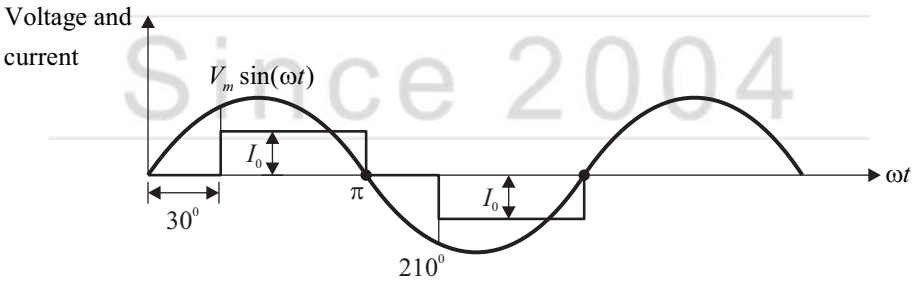




The Fourier series representation of supply current is given by,

$$i_s(t) = \sum_{n=1,\,3,\,5\ldots}^{\infty} \frac{4I_0}{n\pi}\cos\frac{n\alpha}{2}\sin\left(n\omega t - \frac{n\alpha}{2}\right)$$

From the given diagram



The value of firing angle (α) = 30^0

Hence, the RMS value of supply fundamental current in a single phase semi-converter is given by,

$$I_{1_{RMS}} = \frac{\frac{4I_0}{\pi}\times\cos\frac{\alpha}{2}}{\sqrt{2}} = \frac{4\times 20}{\pi\sqrt{2}}\cos 15^0 = 17.39$$

Hence, the RMS value of fundamental component of the supply current is **17.39 A.**

Question 3 (Signals & Systems)

Let f be the real valued function of a real variable defined $f(x) = x - [x]$, where $[x]$ denotes the largest integer less than or equal to *x*. The value of $\int_{0.25}^{1.25} f(x)dx$ is _____ (up to 2 decimal plces).

Ans. 0.5

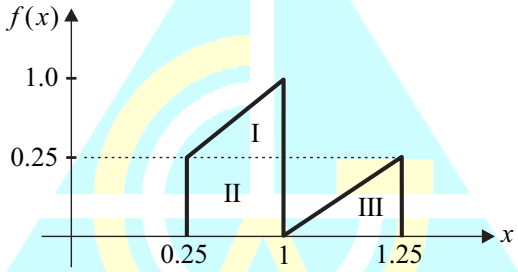
Sol. **Given :** $f(x) = x - [x]$

Where, $[x]$ represents the largest integer less than or equal to *x*.

For $0 \le x < 1 \Rightarrow f(x) = x - [x] = x - 0 = x$

For $1 \le x < 2 \Rightarrow f(x) = x - [x] = x - 1$

So, $$f(x) = \begin{cases} x & 0.25 \le x < 1 \\ x-1 & 1 \le x < 1.25 \end{cases}$$



$\int_{0.25}^{1.25} f(x)dx =$ Area or triangle I + Area of Rectangle II + Area of triangle III

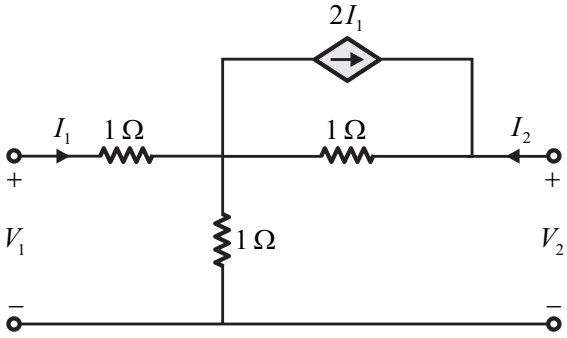
$$= \left(\frac{1}{2} \times 0.75 \times 0.75\right) + (0.75 \times 0.25) + \left(\frac{1}{2} \times 0.25 \times 0.25\right)$$

$$= 0.5$$

Hence, the correct answer is 0**.5.**

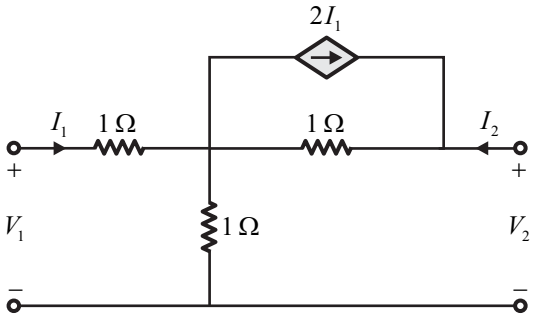
Question 4 (Network Theory)

In the two-port network shown, the h_{11} parameter (where, $h_{11} = \frac{V_1}{I_1}$ when $V_2 = 0$) in ohms is _____ (up to 2 decimal places).

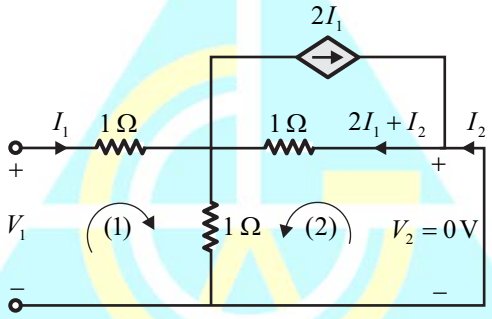


Ans. **0.5**

Sol. **Given :** The two port network is shown below,



To find the value of $h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0}$, the equivalent circuit is shown below,



Applying KVL in loop (1),

$$V_1 - I_1 - (I_1 + I_2) = 0$$

$$V_1 = 2I_1 + I_2 \qquad \ldots(i)$$

Applying KVL in loop (2),

$$(I_1 + I_2) + (2I_1 + I_2) = 0$$

$$3I_1 + 2I_2 = 0 \qquad \ldots(ii)$$

From equation (i) and (ii),

$$V_1 = 2I_1 - \frac{3I_1}{2}$$

$$\frac{V_1}{I_1} = 2 - \frac{3}{2} = \frac{1}{2} = 0.5$$

Hence,

$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0} = 0.5$$

Hence, the correct answer is 0.5

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Question 5 (Power System)

A 1000×1000 bus admittance matrix for an electric power system has 8000 non zero elements. The minimum number of branches (transmission lines and transformers) in this power system are _____ (up to 2 decimal places).

Ans. 3500

Sol. **Given :** A bus system of 1000×1000 contains 8000 non zero elements.

Method 1 :

The total number of elements $=1000\times1000=1000000$

$$\%\text{ of sparcity } (\%\,x)=\frac{1000000-8000}{1000000}\times100=\frac{992000}{1000000}\times100=99.2\%$$

Hence the number of transmission lines $=\dfrac{n^2(1-x)-n}{2}$

$$=\frac{1000^2(1-0.992)-1000}{2}=\frac{8000-1000}{2}=3500$$

Hence, the minimum number of branches are **3500.**

Method 2 :

Number of non-zero element = 8000

Number of diagonal element = 1000

Number of non-zero off diagonal element = 7000

Hence, Number of transmission lines $=\dfrac{\text{Number of non-zero off diagonal element}}{2}=\dfrac{7000}{2}=3500$

Hence, the minimum number of branches are **3500.**

Question 6 (Signals & Systems)

A continuous time input signal $x(t)$ is an eigen function of an LTI system, if the output is

(A) $kx(t)$, where k is an eigen value

(B) $ke^{j\omega t}x(t)$, where k is an eigen value and $e^{j\omega t}$ is a complex exponential signal

(C) $x(t)e^{j\omega t}$, where $e^{j\omega t}$ is a complex exponential signal

(D) $kH(\omega)$, where k is an eigen value and $H(\omega)$ is a frequency response of the system.

Ans. (A)

Sol. If the output signal is a scalar multiple of input signal, the signal is refereed as an eigen function (or characteristic function) and the multiplier is referred as an eigen value (or characteristic value).

If $x(t)$ is the eigen function and λ is the eigen value, then output, $y(t)=\lambda\,x(t)$.

Hence, the correct option is (A).

Question 7 (Engineering Mathematics)

Let f be a real valued function of a real variable defined as $f(x)=x^2$ for $x\geq0$, and $f(x)=-x^2$ for $x<0$. Which of the following statement is true?

(A) $f(x)$ is discontinuous at $x=0$

(B) $f(x)$ is continuous but not differentiable at $x=0$

(C) $f(x)$ is differentiable but its first derivative is not continuous at $x=0$

(D) $f(x)$ is differentiable but its first derivative is not differentiable at $x=0$.

Ans. **(D)**

Sol. **Given :** $f(x)=\begin{cases}x^2 & \text{for } x>0\\ -x^2 & \text{for } x<0\end{cases}$

It's first derivative,

$$f'(x)=\begin{cases}2x & x>0\\ -2x & x<0\end{cases}$$

Let $2x=t \Rightarrow x>0 \Rightarrow t>0$

$x<0 \Rightarrow t<0$

$$f'(x)=\begin{cases}t & t>0\\ -t & t<0\end{cases}$$

$$f'(t)=|t|$$

The first derivative is mod function according to property, it is continuous but not differentiable at $t=0 \Rightarrow x=0$.

Also, $$f''(x)=\begin{cases}2 & x>0\\ -2 & x<0\end{cases}$$

First derivative is not differentiable.

Hence, the correct option is (D).

Question 8 (Control System)

Consider a unity feedback system with forward transfer function is given by,

$$G(s)=\frac{1}{(s+1)(s+2)}$$

The steady state error in the output of the system for a unit-step input is _____ (up to 2 decimal places).

Ans. **0.67**

Sol. **Given :** The open loop transfer function for given unity feedback system is

$$G(s)H(s)=\frac{1}{(s+1)(s+2)} \qquad [H(s)=1]$$

Steady state error for unit step input $(e_{ss})=\frac{1}{1+K_p}$

Where, K_p(Position error coefficient) $=\lim_{s\to 0}G(s)H(s)$

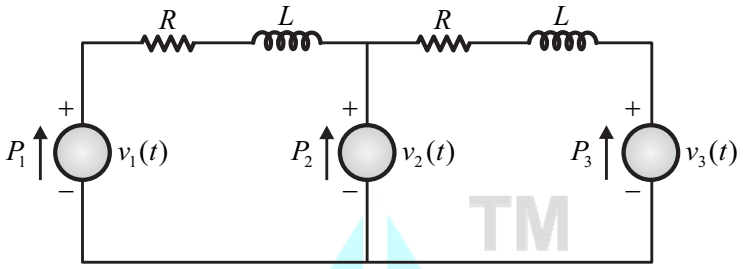
$$K_p=\lim_{s\to 0}\frac{1}{(s+1)(s+2)}=\frac{1}{2}$$

Steady state error $(e_{ss})=\frac{1}{1+\frac{1}{2}}=\frac{1}{1.5}=0.67$

Hence, steady state error in the output of the system for a unit-step input is **0.67.**

Question 9 (Power System)

In the figure, the voltages are $V_1(t)=100\cos(\omega t)$, $V_2(t)=100\cos(\omega t+\pi/18)$ and $V_3(t)=100\cos(\omega t+\pi/36)$. The circuit is in sinusoidal steady state, and $R<<\omega L$, P_1, P_2 and P_3 are the average power outputs. Which one of the following statements is true?



(A) $P_1=P_2=P_3=0$

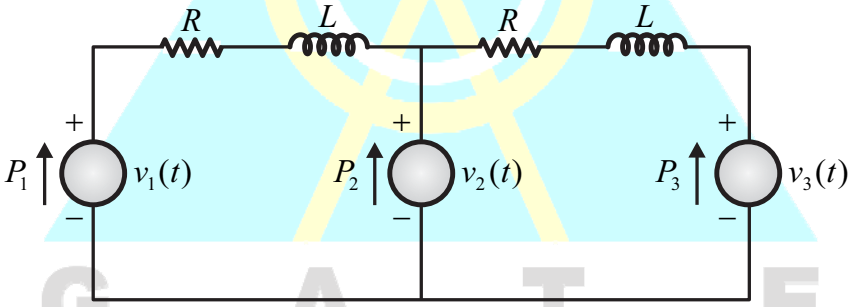
(B) $P_1<0,\ P_2>0,\ P_3>0$

(C) $P_1<0,\ P_2>0,\ P_3<0$

(D) $P_1>0,\ P_2<0,\ P_3>0$

Ans. **(C)**

Sol. **Given :** The circuit is shown below,



$$v_1(t)=100\cos\omega t$$

$$v_2(t)=100\cos\left(\omega t+\frac{\pi}{18}\right)$$

$$v_3(t)=100\cos\left(\omega t+\frac{\pi}{36}\right)$$

From the above expression, it is clear that v_2 is leading v_1 by 10^0 and v_3 is leading v_1 by 5^0. Since, active power (P) is always flow from leading angle to lagging angle. Hence, the current will flow from $v_2(t)$ towards $v_1(t)$ and $v_3(t)$. Hence $P_2>0$ and $P_1<0$ and $P_3<0$.

Hence, the correct option is (C).

Question 10 (Engineering Mathematics)

The value of the integral $\oint_C \frac{z+1}{z^2-4}dz$ in counter clockwise direction around a circle C of radius 1 with center at the point $z=-2$ is

(A) $\frac{\pi i}{2}$ (B) $2\pi i$ (C) $-\frac{\pi i}{2}$ (D) $-2\pi i$

Ans. **(A)**

Sol. **Given :** $\oint_C \frac{z+1}{z^2-4}dz$

Counter $C|z+2|=1$

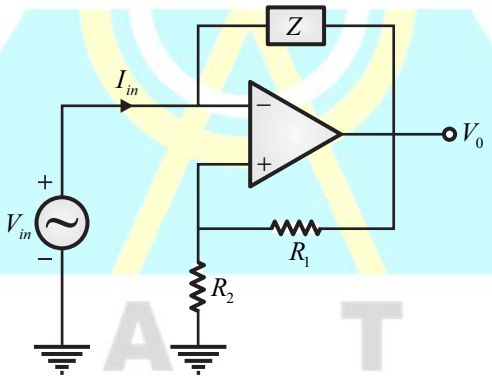
This counter only encircles $z = -2$ pole and hence we need residue at $z = -2$.

$$\oint_C \frac{z+1}{z^2-4}dz = 2\pi i \,\text{Res}\left[f(z)\right]_{z=-2} = 2\pi i \lim_{z\to 2}(z+2)\left[\frac{(z+1)}{(z+2)(z-2)}\right] = \frac{2\pi i}{4} = \frac{\pi i}{2}$$

Hence, the correct option is (A).

Question 11 (Analog Electronics)

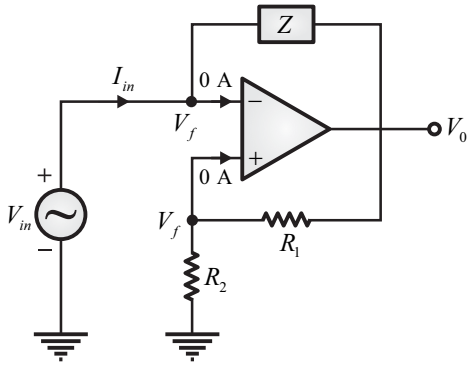
The op-amp shown in the figure is ideal. The input impedance $\frac{v_{in}}{i_{in}}$ is given by



(A) $Z\frac{R_1}{R_2}$ (B) $-Z\frac{R_2}{R_1}$ (C) Z (D) $-Z\frac{R_1}{R_1+R_2}$

Ans. **(B)**

Sol. **Given :** Ideal Op-Amp circuit,



V_0 is acting on series combination of R_1 and R_2

Hence,

$$V_f = \frac{V_0 \times R_2}{R_2 + R_1} \qquad \text{[By VDR]}$$

$$V_{NI} = V_I = V_f \qquad \text{[Due to virtual ground concept]}$$

Also, $V_f = V_{in}$

Applying KCL at inverting terminal,

$$-I_{in} + \frac{V_{in} - V_0}{Z} = 0$$

$$I_{in} = \frac{V_{in} - V_{in} \times \left(1 + \frac{R_1}{R_2}\right)}{Z}$$

$$I_{in} = \frac{V_{in}\left(1 - 1 - \frac{R_1}{R_2}\right)}{Z}$$

$$\frac{V_{in}}{I_{in}} = -Z\frac{R_2}{R_1}$$

Hence, the correct option is (B).

Question 12 (Electrical & Electronics Measurement)

Two wattmeter method is used for measurement of power in a balanced three-phase load supplied from a balanced three-phase system. If one of the wattmeters reads half of the other (both positive), then the power factor of the load is

(A) 0.532 (B) 0.632 (C) 0.707 (D) 0.866

Ans. (D)

Sol. **Given :** Two wattmeter method measuring power in a balanced three phase load supplied from three phase balanced three phase system.

Hence, $W_2 = 2W_1$

The power factor angle is given by,

$$\phi = \tan^{-1}\sqrt{3}\left(\frac{W_2 - W_1}{W_2 + W_1}\right)$$

$$\phi = \tan^{-1}\sqrt{3}\left(\frac{2W_1 - W_1}{2W_1 + W_1}\right)$$

$$\phi = \tan^{-1}\frac{1}{\sqrt{3}} = 30^0$$

Power factor $= \cos\phi = \cos 30^0 = 0.866$.

Hence, the correct option is (D).

Question 13 (Electrical Machine)

In a salient pole synchronous motor, the developed reluctance torque attains the maximum value when the load angle in electrical degrees is

(A) 0 (B) 45 (C) 60 (D) 90

Ans. (B)

Sol. **Given :** A salient pole synchronous motor.

The power flow in a silent pole synchronous machine is given by,

$$P = \frac{E_f V_T}{X_d}\sin\delta + \frac{V_t^2}{2}\left[\frac{1}{X_q} - \frac{1}{X_d}\right]\sin 2\delta$$

The torque produced, $T = \frac{P}{\omega} = \frac{60}{2\pi N_s}\left[\frac{E_f V_T}{X_d}\sin\delta + \frac{V_t^2}{2}\left[\frac{1}{X_q} - \frac{1}{X_d}\right]\right]$

Where, $\frac{E_f V_T}{X_d}\sin\delta =$ Electromagnetic power

The reluctance power is given by,

$$P_{\text{reluctance}} = \frac{V_t^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta$$

To get maximum reluctance torque, the reluctance power must be maximum. Hence the condition for maximum reluctance torque is

$$\sin 2\delta = 1$$

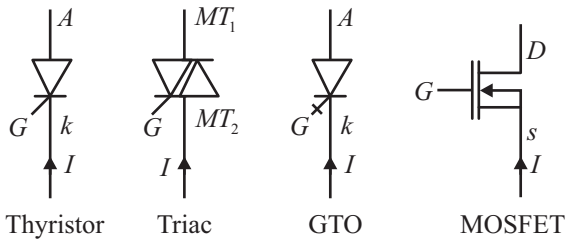
$$2\delta = \sin^{-1}(1) = 90^0$$

$$\delta = \frac{90^0}{2} = 45^0$$

Hence, the correct option is (B).

Question 14 (Power Electronics)

Four power semiconductor devices are shown in the figure along with their relevant terminals. The device (s) that can carry dc current continuously in the direction shown when gated appropriately is (are)



(A) Triac only (B) Triac and MOSFET (C) Triac and GTO (D) Thyristor and triac

Ans. **(A)**

Sol. (i)

Thyristor

An SCR allows only anode to cathode current. Hence the given current can not flow through SCR.

(ii)

Triac

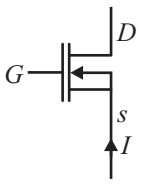
A triac is a bidirectional current flow device. Hence the given current can flow from terminal MT_2 to terminal MT_1.

(iii)

GTO

A GTO is a gate turn off thyristor. It is a unidirectional current flow device. It allows only anode to cathode current. Hence the given current can not flow through GTO.

(iv)



MOSFET

Note : A MOSFET with body diode is a by directional current conduction device. But here the body diode is not mentioned.

The given MOSFET is a D-MOSFET. It allows only drain to source current. Hence the given current can not flow through MOSFET.

Hence, the correct option is (A).

Question 15 (Network Theory)

The graph of a network has 8 nodes and 5 independent loops. The number of branches of the graph is

(A) 11 (B) 12 (C) 13 (D) 14

Ans. **(B)**

Sol. **Given :**

(i) Number of nodes = 8 (ii) Number of independent loop = 5

In graph theory, number of independent loop represents number of links $= b - n + 1$

Hence,

$$b - n + 1 = 5$$
$$b - 8 + 1 = 5$$
$$b = 12$$

Number of branch = 12

Hence, the correct option is (B).

Question 16 (Power System)

The series impedance matrix of a short three-phase transmission line in phase coordinates is $\begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix}$. If the positive sequence impedance is $(1+j10)\Omega$ and the zero sequence is $(4+j31)\Omega$, then the imaginary part of Z_m (in Ω) is _____ (up to 2 decimal places).

Ans. **7**

Sol. The positive sequence impedance $(Z_1) = Z_s - Z_m = 1 + j10$ …(i)

The zero second sequence impedance $(Z_0) = Z_s + 2Z_m = 4 + j31$ …(ii)

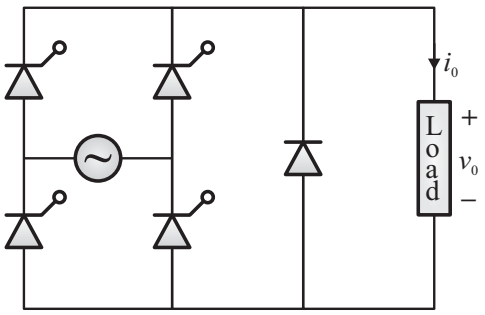
From equation (i) and (ii),

$$Z_0 - Z_1 = 3Z_m = 3 + j21$$
$$Z_m = 1 + j7$$

Hence, imaginary part of Z_m is **7.**

Question 17 (Power Electronics)

A single phase fully controlled rectifier is supplying a load with an anti-parallel diode as shown in the figure. All switches and diodes are ideal. Which one of the following is true for instantaneous load voltage and current?



(A) $v_0 \geq 0$ and $i_0 < 0$ (B) $v_0 < 0$ and $i_0 < 0$ (C) $v_0 \geq 0$ and $i_0 \geq 0$ (D) $v_0 < 0$ and $i_0 \geq 0$

Ans. **(C)**

Sol. **Given :** A single phase fully controlled rectifier with freewheeling diode.

As the converter has freewheeling diode, hence the instantaneous output voltage will never be negative whether the converter is working under continuous mode or discontinuous mode.

The instantaneous value of output current is always unidirectional as it is a AC to DC converter. Here we can think about two cases :

Case I : Discontinuous conduction mode – Here the output current, $i_0 \geq 0$.

Case II : **Continuous conduction mode –** Here the output current, $i_0 > 0$.

Hence, the correct option is (C).

Question 18 (Engineering Mathematics)

The value of the directional derivative of the function $\phi(x, y, z) = xy^2 + yz^2 + zx^2$ at the point (2, – 1, 1) in the direction of the vector $p = i + 2j + 2k$ is

(A) 1 (B) 0.95 (C) 0.93 (D) 0.9

Ans. **(A)**

Sol.

$$\phi = xy^2 + yz^2 + zx^2$$

$$\nabla\phi = \frac{\partial\phi}{\partial x}\hat{i} + \frac{\partial\phi}{\partial y}\hat{j} + \frac{\partial\phi}{\partial z}\hat{k} = (y^2 + 2xz)\hat{i} + (2xy + z^2)\hat{j} + (2yz + x^2)\hat{k}$$

$$\nabla\phi = (2, -1, 1) = 5\hat{i} - 3\hat{j} + 2\hat{k}$$

$$\nabla\phi \cdot \hat{p} = \nabla\phi \cdot \frac{\vec{p}}{|\vec{p}|} = (5\hat{i} - 3\hat{j} + 2\hat{k})\frac{(\hat{i} + 2\hat{j} + 2\hat{k})}{3} = \frac{5 - 6 + 4}{3} = 1$$

Hence, the correct option is (A).

Question 19 (Power System)

The positive negative and zero sequence impedances of a 125 MVA, three-phase, 15.5 kV, star-grounded, 50 Hz generator are $j0.1$pu, $j0.05$ pu and $j0.01$ pu respectively on the machine rating base. The machine is unloaded and working at the rated terminal voltage. If the grounding impedance of the generator is $j0.01$ pu, then the magnitude of fault current for a b-phase to ground fault (in kA) is _____ (up to 2 decimal places).

Ans. **73.52**

Sol. **Given :**

(i) Positive sequence impedance $Z_1 = j0.1$ pu

(ii) Negative sequence impedance $Z_2 = j0.05$ pu

(iii)Zero sequence impedance $Z_0 = j0.01$ pu

(iv)Grounding impedance $Z_g = j0.01$ pu

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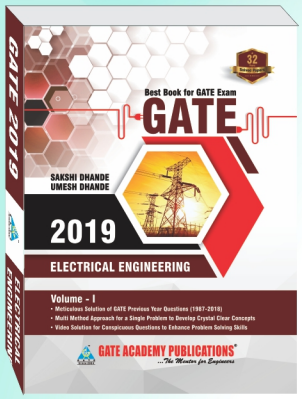

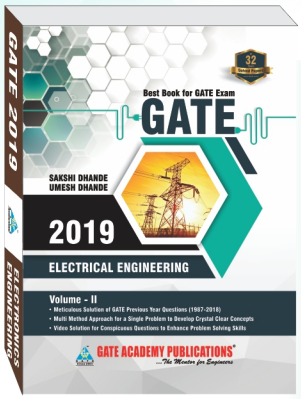

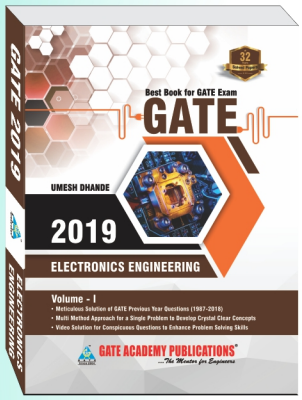

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The magnitude of fault current in LG fault,

$$I_f(\text{pu}) = \frac{3V_{TH}}{Z_1 + Z_2 + Z_0 + 3Z_n} = \frac{3}{0.01 + 0.05 + 0.01 + 3\times 0.01} = \frac{3}{0.19} = 15.789$$

Hence, the value of fault current in actual ampere can be calculated as

$$I_f(\text{pu}) = \frac{I_f}{I_{base}} = \frac{I_f}{\left(\frac{VA}{\sqrt{3}V}\right)}$$

$$I_f = \frac{VA}{\sqrt{3}V} \times I_f(\text{pu}) = \frac{15.789\times 125}{\sqrt{3}\times 15.5} = 73.5166 \text{ kA}$$

Hence, the magnitude of fault current for a b-phase to ground fault is **73.51 kA.**

Question 20 (Control System)

Match the transfer functions of the second-order systems with the nature of the systems given below.

Transfer functions	**Nature of system**
P. $\frac{15}{s^2+5s+15}$	1. Over damped
Q. $\frac{25}{s^2+10s+25}$	II. Critically damped
R. $\frac{35}{s^2+18s+35}$	III. Underdamped

(A) P-I, Q-II, R-III (B) P-II, Q-I, R-III (C) P-III, Q-II, R-I (D) P-III, Q-I, R-II

Ans. **(C)**

Sol.

Option	Characteristic equation	Damping ratio (ξ)	Damping
P.	$s^2+5s+15$	$\xi = 0.645$	Under damping
Q.	$s^2+10s+25$	$\xi = 1$	Critical damped
R.	$s^2+185+35$	$\xi = 1.52$	Over damped

Hence, the correct option is (C).

Question 21 (Engineering Mathematics)

Consider a non-singular 2×2 square matrix A. If trace (A) = 4 and trace (A^2) = 5. The determinant of the matrix A is _____ (up to 1 decimal place).

Ans. **5.5**

Sol. **Given :** Trace (A) = Eigen value $[A] = \lambda_1, \lambda_2 \rightarrow \lambda_1 + \lambda_2 = 4$

Trace (A^2) = Eigen value $[A^2] = \lambda_1^2, \lambda_2^2 \rightarrow \lambda_1^2 + \lambda_2^2 = 5$

Trace $= \Sigma\lambda$, Det. = Prod. (λ)

We have to find det (A) that means.

$$\det(A) = \lambda_1\lambda_2 = ?$$

By squaring trace (A), we get

$$(\lambda_1 + \lambda_2)^2 = (4)^2$$

$$\lambda_1^2 + \lambda_2^2 + 2\lambda_1\lambda_2 = 16$$

Put the value of $\lambda_1^2 + \lambda_2^2$, from trace (A^2), then

$$5 + 2\lambda_1\lambda_2 = 16$$

$$2\lambda_1\lambda_2 = 16 - 5$$

$$\lambda_1\lambda_2 = \frac{11}{2} = 5.5$$

Hence, the determinant of the matrix A is **5.5.**

Question 22 (Electrical Machine)

A separately excited dc motor has an armature resistance $R_a = 0.05\Omega$. The field excitation is kept constant. At an armature voltage of 100 V, the motor produces a torque of 500 Nm at zero speed. Neglecting all mechanical losses, the no-load speed of the motor (in radians) for an armature voltage of 150 V is _____ (up to 2 decimal places.)

Ans. 600

Sol. Given :

1. Separately excited DC motor
2. Field excitation (ϕ) = Constant

Case I : At zero speed ($N = 0$), torque $(T) = 500\,\text{Nm}$, induced voltage $(E) = 0$

$$T = K\phi I_a$$

$$T = K' I_a \qquad [\text{as } \phi = \text{Constant}]$$

$$E = V - I_{a_1} R_a$$

$$I_{a_1} = \frac{V - E}{R_a} = \frac{100 - 0}{0.05} = 2000\,\text{A}$$

Hence, $$K' = \frac{T}{I_{a_1}} = \frac{500}{2000} = \frac{1}{4}$$

Case II : No load condition,

At no load, load torque $(T_L) = 0$, $E_2 I_{a_2} = T\omega = 0 \times \omega = 0$, and $I_{a_2} = 0$

Induced voltage, $E_2 = K\phi\omega_2 = K'\omega_2 = 150\text{ V}$, and $K' = \frac{1}{4} = \text{Constant}$

$$\omega_2 = \frac{E_2}{K'} = \frac{150}{\frac{1}{4}} = 600\text{ rad/sec}$$

Hence, at no load motor will operate at **600 rad/sec**.

Question 23 **(Power System)**

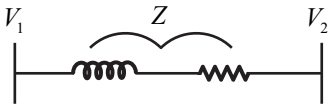
Consider a lossy transmission line with V_1 and V_2 as the sending and receiving end voltages, respectively. Z and X are the series impedance and reactance of the line, respectively. The steady-state stability limit for the transmission line will be

(A) greater than $\left|\frac{V_1V_2}{X}\right|$ (B) less than $\left|\frac{V_1V_2}{X}\right|$ (C) equal to $\frac{V_1V_2}{X}$ (D) equal to $\frac{V_1V_2}{Z}$

Ans. **(B)**

Sol. **Given :** A lossy transmission line

Case I : Power with impedance (Z)



$$P = \frac{V_1V_2}{|z|}\cos(\theta-\delta) - \frac{V_2^2}{|z|}\cos\theta$$

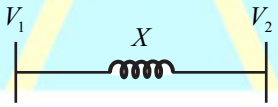
Where, θ = Impedance angle and δ = Load angle

To get maximum power, $\delta = \theta$

Hence,

$$P_{max} = \frac{V_1V_2}{|z|} - \frac{V_2^2}{|z|}\cos\theta$$

Case II : Power with reactance,



$$P' = \frac{V_1V_2}{X}\sin\delta$$

To get maximum power, $\delta = 90^0$

Hence, $P'_{max} = \frac{V_1V_2}{X}$

From above analysis, it is clear that $P'_{max} > P_{max}$

Hence, the maximum power with resistance is less than the maximum power without resistance.

Hence, the correct option is (B).

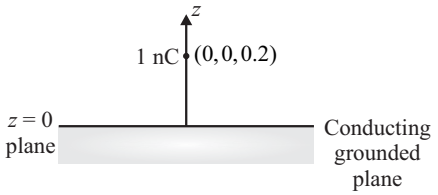
Question 24 **(Electromagnetic Field)**

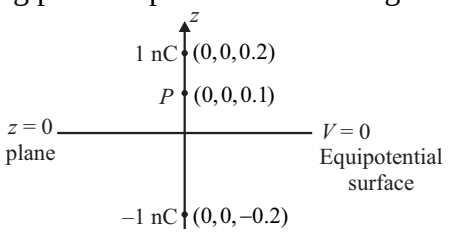
A positive charge of 1nC is placed at (0, 0, 0.2) where all dimensions are in metres. Consider the x-y plane to be a conducting ground plane. Take $\varepsilon_0 = 8.85\times10^{-12}$ F/m . The Z component of the E field at (0, 0, 0.1) is closest to

(A) 899.18 V/m (B) – 899.18 V/m (C) 999.09 V/m (D) – 999.09 V/m

Ans. **(D)**

Sol. **Given :** Charge $=1\text{nC}$ at $(0,0,0.2)$. Since the charge is placed above conducting grounded plane there will be an image charge below the grounded conducting plane as per method of image concept.





Electric field at any point is given by,

$$\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{Q\vec{R}}{\left|\vec{R}\right|^3}$$

$\vec{R}=$ displacement vector between charge to point of interest.

Electric field at point P due to point charge $+1\text{nC}$,

$$\vec{E}_1=\frac{1}{4\pi\varepsilon_0}\frac{1\times10^{-9}\left[(0-0)\vec{a}_x+(0-0)\vec{a}_y+(0.1-0.2)\vec{a}_z\right]}{(0.1)^3}$$

$$\vec{E}_1=-898.755\,\text{V/m}$$

Electric field point P due to point charge -1nC,

$$\vec{E}_2=\frac{1}{4\pi\varepsilon_0}\frac{-1\times10^{-9}\left[(0-0)\vec{a}_x+(0-0)\vec{a}_y+(0.1+0.2)\vec{a}_z\right]}{(0.3)^3}=-99.86\,\text{V/m}$$

Total electric field at point P due to both charges,

$$\vec{E}_1=\vec{E}_1+\vec{E}_2$$

$$\vec{E}=-898.755-99.86=-998.61\,\text{V/m}$$

Hence, the correct option is (D).

Question 25 (Electrical Machine)

A single-phase 100 kVA. 1000 V/100 V. 50 Hz transformer has a voltage drop of 5% across its series impedance at full load. Of this, 3% is due to resistance. The percentage regulation of the transformer at full load with 0.8 lagging power factor is

(A) 4.8 (B) 6.8 (C) 8.8 (D) 10.8

Ans. **(A)**

Sol. **Given :**

(i) $\%R=3\%,\ \%Z=5\%$

(ii) Power factor (pf) = 0.8 lagging

Also, $\%X=\sqrt{Z^2-R^2}=\sqrt{5^2-3^2}=4\%$

As at full load, $x=$ Fraction of loading = 1.

Hence, voltage regulation (V.R.) $=x(\%R\cos\phi+\%X\sin\phi)$

$$\text{V.R.}=1(3\times0.8+4\times0.6)=2.4+2.4=4.8\%$$

Hence, the correct option is (A).

Q.26 to Q.55 carry two marks each

Question 26 (Power System)

The positive, negative and zero sequence impedances of a three phase generator are Z_1, Z_2 and Z_0 respectively. For a line-to-line fault with fault impedance Z_f, the fault current is $I_{f1} = kI_f$, where I_f is the fault current with zero fault impedance. The relation between Z_f and k is

(A) $Z_f = \dfrac{(Z_1 + Z_2)(1-k)}{k}$

(B) $Z_f = \dfrac{(Z_1 + Z_2)(1+k)}{k}$

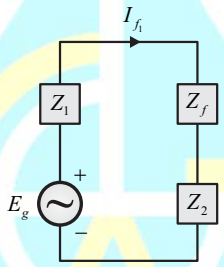
(C) $Z_f = \dfrac{(Z_1 + Z_2)k}{1-k}$

(D) $Z_f = \dfrac{(Z_1 + Z_2)k}{1+k}$

Ans. (A)

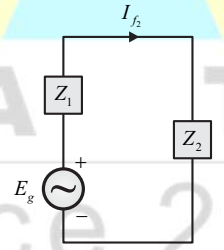
Sol. **Given :** Line to line fault

Case I : Fault current with Z_f



$$I_{f_1} = \frac{\sqrt{3}E_g}{Z_1 + Z_2 + Z_f}$$

Case II : Fault current without Z_f



$$I_{f_2} = \frac{\sqrt{3}E_g}{Z_1 + Z_2}$$

As, $I_{f_1} = kI_{f_2}$

$$\frac{\sqrt{3}E_g}{Z_1 + Z_2 + Z_f} = \frac{k\sqrt{3}E_g}{Z_1 + Z_2}$$

$$Z_1 + Z_2 = k(Z_1 + Z_2) + kZ_f$$

$$Z_f = \frac{(Z_1 + Z_2)(1-k)}{k}$$

Hence, the correct option is (A).

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Question 27 (Signals & Systems)

Consider the two continuous-time signals defined below :

$$x_1(t)=\begin{cases}|t|, & -1\le t\le 1\\ 0, & \text{otherwise}\end{cases}, \qquad x_2(t)=\begin{cases}1-|t|, & -1\le t\le 1\\ 0, & \text{otherwise}\end{cases}$$

These signals are sampled with a sampling period of $T = 0.25$ seconds to obtain discrete-time signals $x_1[n]$ and $x_2[n]$, respectively. Which one of the following statements is true?

(A) The energy of $x_1[n]$ is greater than the energy of $x_2[n]$

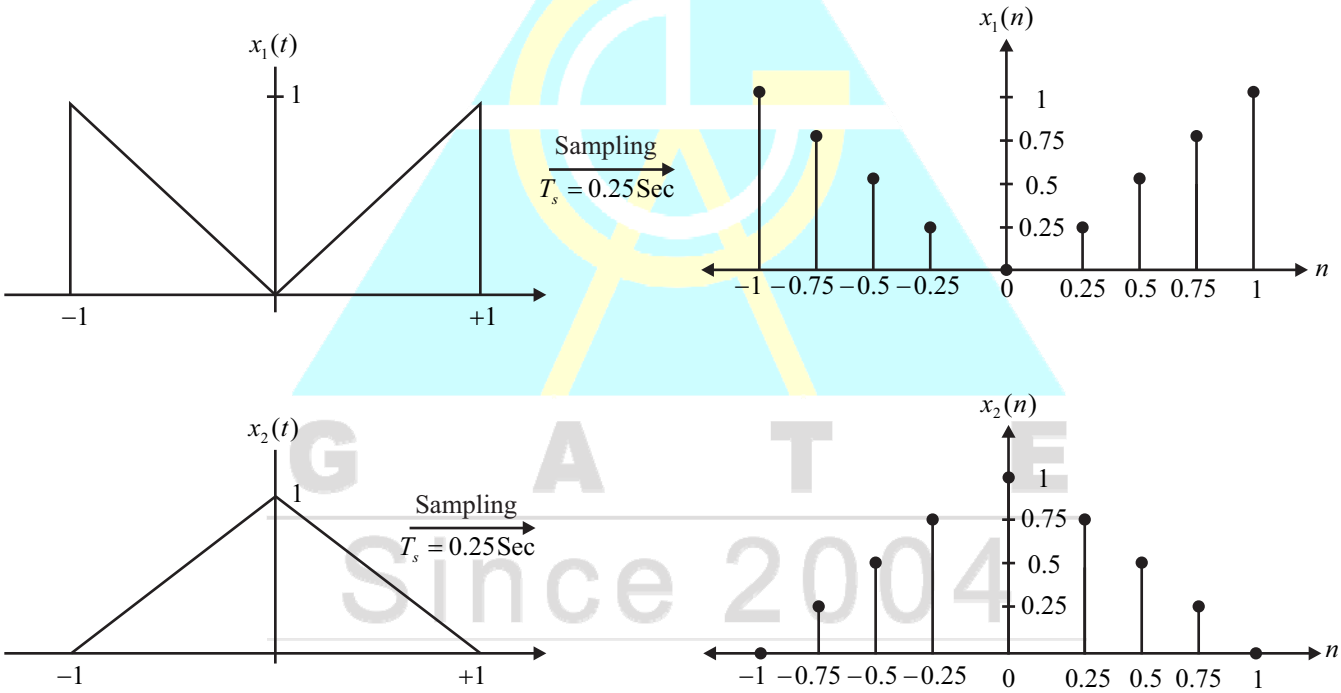
(B) The energy of $x_2[n]$ is greater than the energy of $x_1[n]$.

(C) $x_1[n]$ and $x_2[n]$ have equal energies.

(D) Neither $x_1[n]$ nor $x_2[n]$ is a finite-energy signal.

Ans. **(A)**

Sol.



$$E_1=\sum_{n=-\infty}^{\infty}|x_1(n)|^2=0^2+2\left[1^2+0.75^2+0.5^2+0.25^2\right] \qquad \ldots(i)$$

$$E_2=\sum_{n=-\infty}^{\infty}|x_2(n)|^2=1^2+2\left[0.75^2+0.5^2+0.25^2+0^2\right] \qquad \ldots(ii)$$

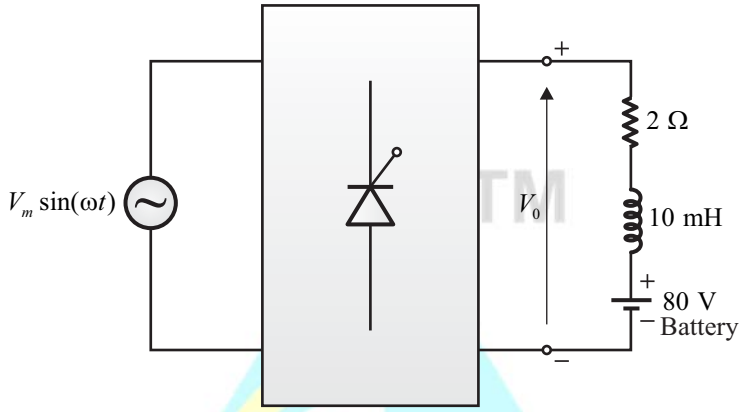
From equation (i) and (ii)

$E_1 > E_2$

Hence, the correct option is (A).

Question 28 (Power Electronics)

A phase controlled single phase rectifier, supplied by an AC source, feeds power to an R-L-E load as shown in the figure. The rectifier output voltage has an average value given $V_0 = \frac{V_m}{2\pi}(3+\cos\alpha)$, where $V_m = 80\pi$ volts and α is the firing angle. If the power delivered to the lossless battery is 1600 W, α in degree is _____(up to 2 decimal places).



Ans. 90

Sol. **Given :** Power transfer to the 80 V battery, $EI_0 = 1600\,\text{W}$

Hence, $I_0 = \frac{1600}{80} = 20\,\text{A}$

$$V_0 = \frac{V}{2\pi}(3+\cos\alpha) = \frac{80\pi}{2\pi}(3+\cos\alpha)$$

$$V_0 = 40(3+\cos\alpha) \quad \ldots(\text{i})$$

The relation between V_0 and E is given by,

$$V_0 = I_0R + E = 20\times 2 + 80$$

$$V_0 = 40 + 80 = 120\,\text{V}$$

From equation (i),

$$V_0 = 120 = 40(3+\cos\alpha)$$

$$\cos\alpha = \frac{120}{40} - 3 = 0$$

$$\alpha = \cos^{-1}(0) = 90^0$$

Hence, the firing angle (α) will be $\mathbf{90^0}$.

Question 29 (Electrical & Electronics Measurement)

A 0-1 Ampere moving iron ammeter has an internal resistance of 50 mΩ and inductance of 0.1 mH. A shunt coil is connected to extend its range to 0-10 Ampere for all operating frequencies. The time constant in milliseconds and resistance in mΩ of the shunt coil respectively are

(A) 2, 5.55 (B) 2, 1 (C) 2.18, 0.55 (D) 11.1, 2

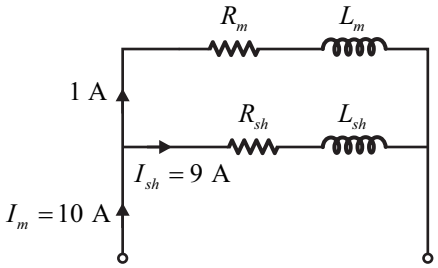
Ans. **(A)**

Sol. **Given :** $I_m = 1$ A (meter current)

$I = 10$ A (extended current)

$R_m = 50\ \text{m}\Omega$ (meter resistance)

$L_m = 0.1$ mH (meter inductance)



$$\frac{I_m}{I_{sh}} = \frac{Z_{sh}}{Z_m} = \sqrt{\frac{R_{sh}^2 + (\omega L_{sh})^2}{R_m^2 + (\omega L_m)^2}}$$

$$\frac{I_m}{I_{sh}} = \frac{R_{sh}\sqrt{1 + \left(\frac{\omega L_{sh}}{R_{sh}}\right)^2}}{R_m\sqrt{1 + \left(\frac{\omega L_m}{R_m}\right)^2}}$$

$$\frac{I_m}{I_{sh}} = \frac{R_{sh}\sqrt{1 + (\omega\tau_{sh})^2}}{R_m\sqrt{1 + (\omega\tau_m)^2}}$$

For the meter to be independent of frequency time constant of meter should be equal to time constant of shunt. i.e. $\tau_{sh} = \tau_m$

$$\frac{I_m}{I_{sh}} = \frac{R_{sh}}{R_m} = \frac{1}{9}$$

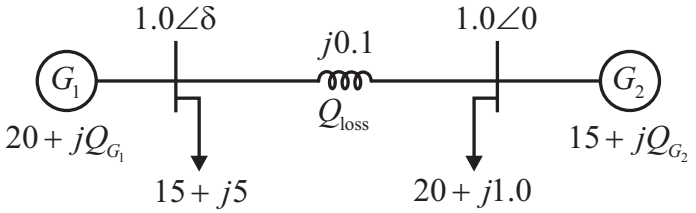
$$R_{sh} = \frac{R_m}{9} = \frac{50\ \text{m}\Omega}{9} = \mathbf{5.55\ m\Omega}$$

Now, $\tau_m = \dfrac{0.1\ \text{mH}}{50\ \text{m}\Omega} = 2$ sec and as system is independent of frequency $\tau_m = \tau_{sh} = \mathbf{2\ sec}$

Hence, the correct option is (A)

Question 30 (Power System)

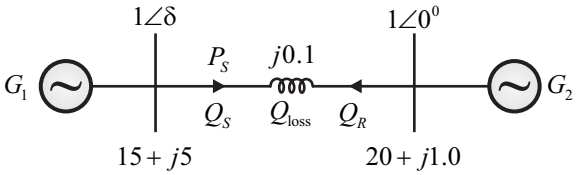
Consider the two bus power system network with given loads as shown in the figure. All the values shown in the figure are in per unit. The reactive power supplied by generator G_1 and G_2 are Q_{G_1} and Q_{G_2} respectively. The per unit values of Q_{G_1}, Q_{G_2} and line reactive power loss (Q_{loss}) respectively are



(A) 5.00, 12.68, 2.68 (B) 6.34, 10.00, 1.34 (C) 6.34, 11.34, 2.68 (D) 5.00, 11.34, 1.34

Ans. **(C)**

Sol. **Given :**



At G_2 load demand is 20 pu, G_2 supplies only 15. Remaining supplied by G_1 through transmission line.

$$P_s = \left|\frac{V_S V_R}{X_L}\right| \sin\delta$$

$$5 = \frac{1\times 1}{0.1}\sin\delta$$

$$\delta = 30^0$$

$$Q_S = \frac{V_S^2}{X_L} - \frac{V_S V_R}{X_L}\cos\delta$$

$$Q_S = \frac{1^2}{0.1} - \frac{1\times 1}{0.1}\cos 30^0 = 1.34\,\text{p.u.}$$

$$Q_R = \left|\frac{V_S V_R}{X_L}\right|\cos\delta - \left|\frac{V_R^2}{X_L}\right|$$

$$Q_R = \left|\frac{1\times 1}{0.1}\right|\cos 30^0 - \frac{1^2}{0.1} = -1.34\,\text{p.u.}$$

$$Q_{loss} = Q_S - Q_R$$

$$Q_{loss} = 1.34 - (-1.34) = 2.68\,\text{p.u.}$$

At G_1 : $Q_{G1} = Q_{load} + Q_S$

$$Q_{G1} = 5 + 1.34 = 6.34\,\text{p.u.}$$

At G_2 : $Q_{G2} = Q_{load} + (-Q_R)$

$$Q_{G2} = 10 - (-1.34) = 11.34\,\text{p.u.}$$

Hence, the correct option is (C).

Question 31 **(Power Electronics)**

The figure shows two buck converters connected in parallel. The common input dc voltage for the converters has value of 100 V. The converters have inductors of identical value. The load resistance is $1\,\Omega$. The capacitor voltage has negligible rippel. Both converters operate in the continuous conduction mode. The switching frequency is 1 kHz, and the switch control signals are as shown. The circuit operates in the steady state. Assume that the converters share the load equally, the average value of i_{s_1}, the current of switch S_1 (in ampere), is _____ (up to 2 decimal places).

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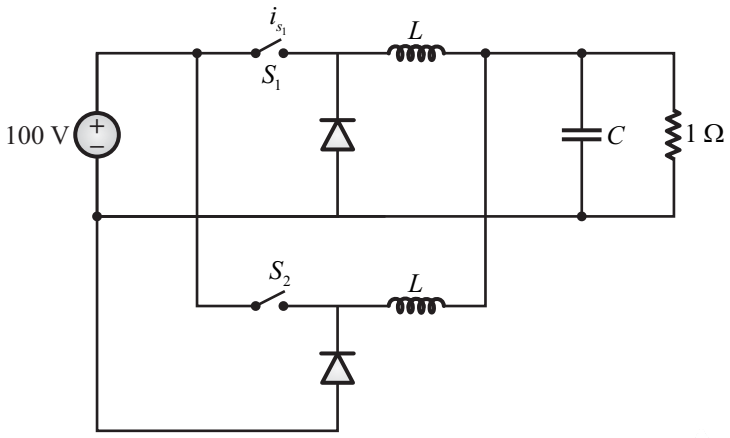
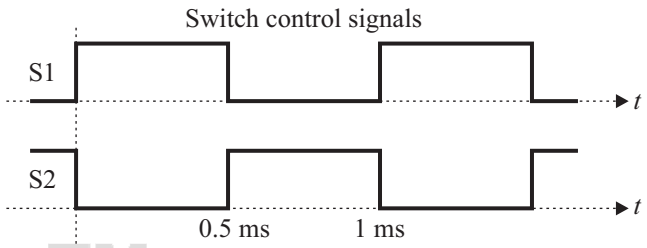




Ans. **25**

Sol. **Given :**

(i) $V_s = 100\,\text{V}$

(ii) Interleaved converters.

(iii) Load resistance $= 1\,\Omega$

(iv) Switching frequency = 1 kHz

Case I : When $S_1 \rightarrow$ ON, $S_2 \rightarrow$ Open

$$V_0 = V_S \qquad \text{(As the average voltage across inductor is zero at steady state)}$$

Case II : When $S_2 \rightarrow$ ON, $S_1 \rightarrow$ Open

$$V_0 = V_S \qquad \text{(As the average voltage across inductor is zero steady state)}$$

Hence, V_0 is always equal to V_S

$$I_0 = \frac{V_0}{R} = \frac{100}{1} = 100\,\text{A}$$

Since the load current is equal divided in two inductive element. Hence,

$$I_{L1(avg)} = I_{L2(avg)} = 50\,\text{A}$$

Now

$$I_{s1(avg)} = DI_{L1(avg)} \quad \text{and} \quad I_{s2(avg)} = DI_{L2(avg)}$$

Where, $D = \text{Duty ratio} = \frac{T_{ON}}{T} = \frac{0.5}{1} = 0.5$

Hence, $I_{s1(avg)} = DI_{L1(avg)} = 0.5 \times 50 = 25\,\text{A}$

$$I_{s2(avg)} = DI_{L2(avg)} = 0.5 \times 50 = 25\,\text{A}$$

Hence, the average value of switch (S_1) current is **25 A.**

Question 32 (Electrical Machine)

A 200 V DC series motor, when operating from rated voltage while driving a certain load, draws 10 A current and runs at 1000 rpm. The total series resistance is $1\,\Omega$. The magnetic circuit is assumed to be linear. At the same supply voltage, the load torque is increased by 44%. The speed of the motor in rpm (rounded to the nearest integer) is _____.

Ans. **825**

Sol. **Given :** DC series motor

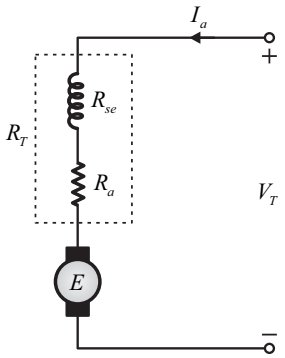
(i) Terminal voltage, $V_T = 200$ V

(ii) $I_{a1} = 10$ A $\quad N_1 = 1000$ rpm

(iii) $R_T = R_a + R_{se} = 1\,\Omega$

(iv) $\phi \propto I$ (Linear magnetization)

(v) $T_2 = 1.44T_1$



A DC series motor circuit is shown below,

For motor, $T = \dfrac{Z\phi PI_a}{2\pi A} = k\phi I_a$

For, DC series motor $\phi \propto I_a$

$$T \propto I_a^2$$

$$\frac{T_2}{T_1} = \frac{I_{a2}^2}{I_{a1}^2} = 1.44$$

$$I_{a2} = 1.2I_{a1} = 12 \text{ A}$$

Also, $E \propto \phi N$

$$\frac{E_2}{E_1} = \frac{\phi_2 N_2}{\phi_1 N_1}$$

$$N_2 = \frac{E_2}{E_1} \times \frac{\phi_1}{\phi_2} \times N_1 = \frac{E_2 I_{a1}}{E_1 I_{a2}} N_1 \quad \ldots \text{(i)}$$

$$E_1 = V_T - I_{a1}R_T = 200 - 10 \times 1 = 190 \text{ V}$$

$$E_2 = V_T - I_{a2}R_T = 200 - 12 \times 1 = 188 \text{ V}$$

$$N_2 = \frac{188}{190} \times \frac{1}{1.2} \times 1000 = 824.56 \text{ rpm}$$

Hence, the speed of the motor (rounded to the nearest integer) is **825 rpm.**

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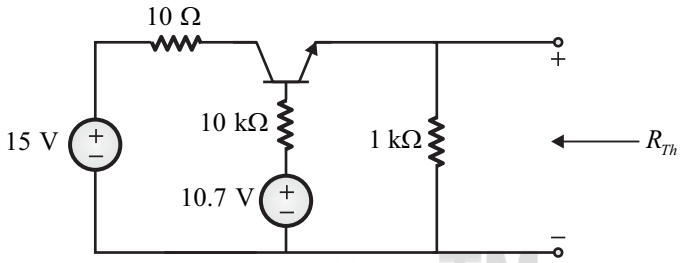
Question 33 (Analog Electronics)

In the circuit shown in the figure, the bipolar junction transistor (BJT) has a current gain $\beta = 100$. The base-emitter voltage drop is a constant, $V_{BE} = 0.7\,\text{V}$. The value of the Thevenin equivalent resistance R_{Th} (in Ω) as shown in the figure is _____ (up to 2 decimal places).

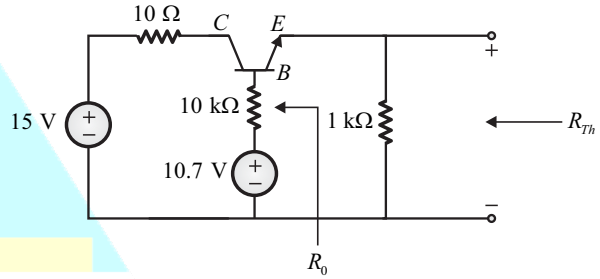


Ans. 2.76

Sol. **Given :** Common collector amplifier

$$R_{TH} = R_0 \,||\, 1\text{k}\Omega$$

Where, R_0 is output impedance as seen in the figure equal to output impedance of common collector amplifier



$$R_0 = \frac{1}{g_m} \,||\, 1000$$

$$g_m = \frac{I_C}{V_T}$$

Applying KVL in B-E loop,

$$-10.7 + 10I_B + 0.7 + (I_B + I_C) \times 1 = 0$$

$$10 = 101I_B + 10I_B$$

$$10 = 111I_B$$

$$I_B = \frac{10}{111}\text{mA}$$

$$I_C = \beta I_B = \frac{1000}{11}\text{mA}$$

$$g_m = \frac{I_C}{V_T} = \frac{40}{111}\text{A/V}$$

$$R_0 = \frac{R_s + h_{ie}}{1 + h_{fe}} = \frac{10 + \frac{\beta}{g_m}}{\beta} = \frac{10}{\beta} + \frac{1}{g_m}$$

$$0.1 + 2.775 = 2.875$$

$$R_{TH} = R_0 \,||\, 1000 = 2.86\,\Omega$$

Hence, the correct answer is **2.86.**

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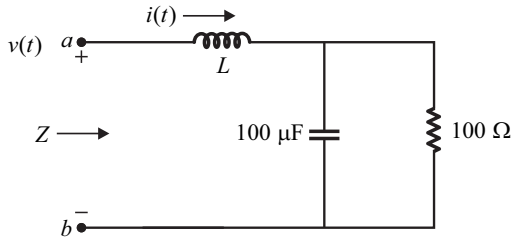
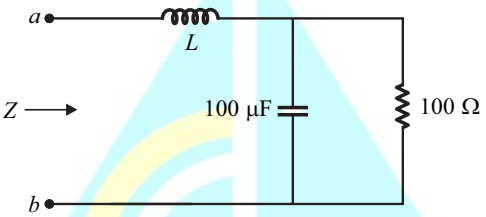
Question 34 **(Network Theory)**

The voltage $v(t)$ across the terminals a and b as shown in the figure, is a sinusoidal voltage having a frequency $\omega = 100$ radian/s. When the inductor current $i(t)$ is in phase with the voltage $v(t)$, the magnitude of the impedance Z (in Ω) seen between the terminals *a* and *b* is _____ (up to 2 decimal places).



Ans. **50**

Sol. **Given :**



$$Z = \frac{100\left(\frac{1}{j\omega C}\right)}{100-\left(\frac{j}{\omega C}\right)} + j\omega L = \frac{-\frac{j100}{\omega C}\left(100+\frac{j}{\omega C}\right)}{100^2+\frac{1}{\omega^2C^2}} + j\omega L$$

Since, the power factor is unity, unity power factor represents resonance.

So, imaginary part of Z is zero only real part exist.

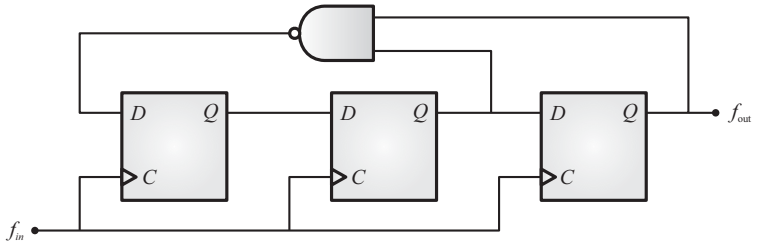
$$\text{Re}(Z) = \frac{\frac{100}{\omega^2C^2}}{100^2+\frac{1}{\omega^2C^2}} = \frac{100}{(100\omega C)^2+1} = \frac{100}{(100\times100\times100\times10^{-6})^2+1}$$

$$\text{Re}(Z) = 50\ \Omega$$

Hence, the magnitude of the impedance Z seen between the terminals *a* and *b* is **50 Ω .**

Question 35 **(Digital Electronics)**

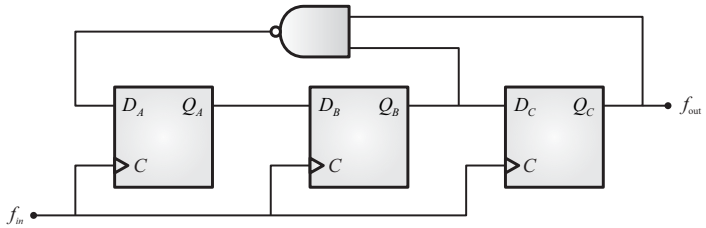
Which one of the following statements is true about the digital circuit shown in the figure.



(A) It can be used for dividing the input frequency by 3.
(B) It can be used for dividing the input frequency by 5.
(C) It can be used for dividing the input frequency by 7.
(D) It cannot be reliably used as a frequency divider due to disjoint internal cycles.

Ans. 5

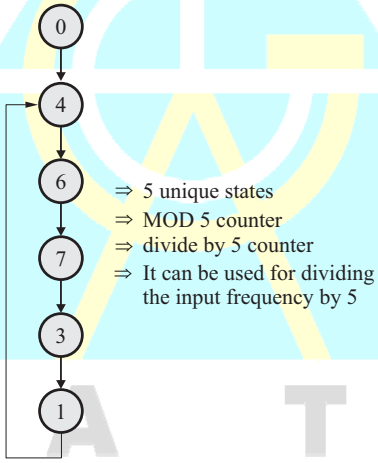
Sol. **Given :**

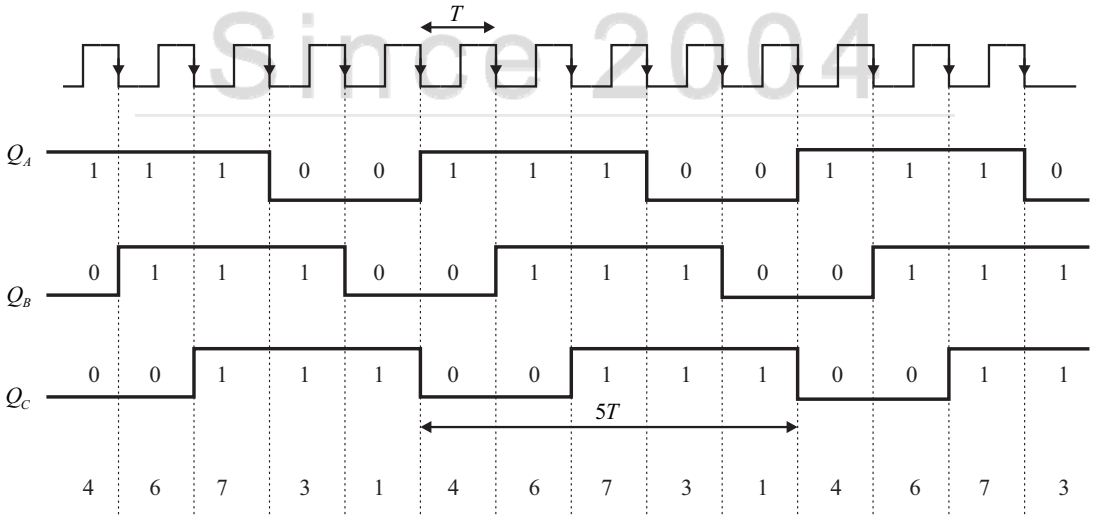


From the above sequential circuit,

Present state			FF inputs			Next state		
θ_A	θ_B	θ_C	$D_A = \overline{\theta_B \cdot \theta_C}$	$D_B = \theta_A$	$D_C = \theta_B$	θ_A^+	θ_B^+	θ_C^+
0	0	0	1	0	0	1	0	0
1	0	0	1	1	0	1	1	0
1	1	0	1	1	1	1	1	1
1	1	1	0	1	1	0	1	1
0	1	1	0	0	1	0	0	1
0	0	1	1	0	0	1	0	0

State diagram :



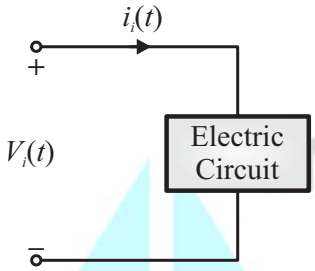


Question 36 (Network Theory)

The voltages across the circuit in the figure, and the current through it are given that the following expressions :

$V_i(t) = 5 - 10\cos(\omega t + 60)$ and $i_i(t) = 5 + X\cos(\omega t)$

Where $\omega = 100\pi$ rad/sec . If the average power delivered to the circuit is zero then the value of X (in ohm) is _____ (upto two decimal places)



Ans. 10

Sol. **Given :**

(i) $V_i(t) = 5 - 10\cos(\omega t + 60)$

(ii) $i_i(t) = 5 + X\cos\omega t$

The average power is given by,

$$P_{avg} = V_0 I_0 - V_{01} I_{01}\cos\phi_1$$

Where, $V_{01} I_{01}\cos\phi_1 =$ Fundamental power.

Hence,

$$P_{avg} = (5\times 5) - \frac{10\times X}{2}\cos 60 = 0$$

$$25 = \frac{10X}{2}\cos 60$$

$$25 = \frac{10X}{2}\times\frac{1}{2}$$

$$X = \frac{100}{10} = 10$$

Hence, the value of X is **10 Ω.**

Question 37 (Engineering Mathematics)

Let $A = \begin{bmatrix} 1 & 0 & -1 \\ -1 & 2 & 0 \\ 0 & 0 & -2 \end{bmatrix}$ and $B = A^3 - A^2 - 4A + 5I$ where, I is the 3×3 identity matrix. The determinant of B is _____.(upto one decimal places)

Ans. **1**

Sol. To find the eigen value of A,

$$|A-\lambda I|=0$$

$$\begin{vmatrix} 1-\lambda & 0 & -1 \\ -1 & 2-\lambda & 0 \\ 0 & 0 & -2-\lambda \end{vmatrix}=0$$

$$(-2-\lambda)(2-\lambda)(1-\lambda)=0$$

$$\lambda=1,\ 2,\ -2$$

$$B=A^3-A^2-4A+5I$$

The eigen value of matrix B is given by,

$$\lambda_1=1^3-1^2-4+5=1$$

$$\lambda_2=2^3-2^2-(4\times 2)+5=1$$

$$\lambda_3=(-2)^3-(-2)^2-[4\times(-2)]+5=1$$

$$|B|=\lambda_1\lambda_2\lambda_3=1\times 1\times 1=1$$

Hence, the determinant of B is **1.**

Question 38 (Signals & Systems)

The signal energy of the continuous time signal

$$x(t)=\left[(t-1)u(t-1)\right]-\left[(t-2)u(t-2)\right]-\left[(t-3)u(t-3)\right]+\left[(t-4)u(t-4)\right] \text{ is}$$

(A) $\frac{11}{3}$ (B) $\frac{7}{3}$ (C) $\frac{1}{3}$ (D) $\frac{5}{3}$

Ans. **(D)**

Sol. we know that, $r(t)=tu(t)$

put $t=t-1\Rightarrow r(t-1)=(t-1)u(t-1)$

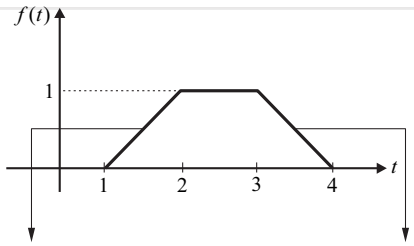
put $t=t-2\Rightarrow r(t-2)=(t-2)u(t-2)$

put $t=t-3\Rightarrow r(t-3)=(t-3)u(t-3)$

put $t=t-4\Rightarrow r(t-4)=(t-4)u(t-4)$

Given : $f(t)=(t-1)u(t-1)-(t-2)u(t-2)-(t-3)u(t-3)+(t-4)u(t-4)$

$$f(t)=r(t-1)-r(t-2)-r(t-3)+r(t-4)$$



$$f(t)-0=\frac{1-0}{2-1}(t-1)$$

$$f(t)=t-1$$

$$f(t)-1=\frac{0-1}{4-3}(t-3)$$

$$f(t)=-t+3+1$$

$$f(t)=-t+4$$

$$E=\int_{-\infty}^{\infty}|f(t)|^2\,dt=\int_{1}^{2}(t-1)^2+\int_{2}^{3}1^2\,dt+\int_{3}^{4}(4-t)^2\,dt$$

$$E=\int_{1}^{2}(t^2+1-2t)+\int_{2}^{3}1^2\,dt+\int_{3}^{4}(16+t^2-8t)dt$$

$$E=\left(\frac{t^3}{3}+t-t^2\right)_1^2+(t)_2^3+\left(16t+\frac{t^3}{3}-4t^2\right)_3^4$$

$$E=\left(\frac{8}{3}+2-4-\frac{1}{3}-1+1\right)+(3-2)+\left(64+\frac{64}{3}-64-48-9+36\right)$$

$$E=\frac{5}{3}$$

Hence, the correct option is (D).

Question 39 (Power System)

The per unit power output of a salient pole generator which is connected to an infinite bus is given by the expression, $P=1.4\sin\delta+0.15\sin 2\delta$, where δ is the load angle. Netwton Raphson method is used to calculate the value of δ for $P=0.8$ pu. If the initial guess is 30^0, then its value (in degree) at the end of the first iteration is

(A) 15^0 (B) 28.48^0 (C) 28.74^0 (D) 31.20^0

Ans. **(C)**

Sol. **Given :** $P=1.4\sin\delta+0.15\sin 2\delta$, $P=0.8$, $\delta_0=30^0$

$$f(\delta)=1.4\sin\delta+0.15\sin 2\delta-0.8$$

$$\delta_{n+1}=\delta_n-\frac{f(\delta)}{f'(\delta)}$$

$$\delta_1=\delta_0-\frac{1.4\sin\delta+0.15\sin 2\delta-P}{1.4\cos\delta+0.3\cos 2\delta}$$

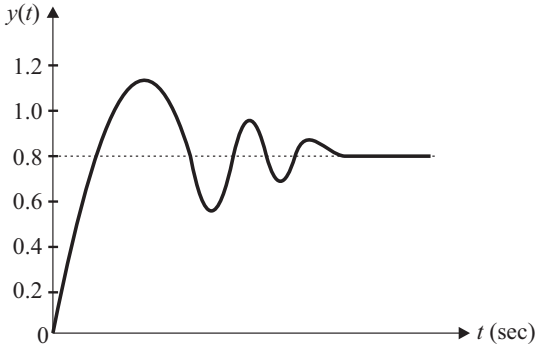
$$\delta_1=\frac{\pi}{6}-\frac{1.4\sin 30+0.15\sin 60-0.8}{1.4\cos 30+0.3\cos 60}=0.50164 \text{ rad}$$

$$\delta_1(30)=28.74^0$$

Hence, the correct option is (C).

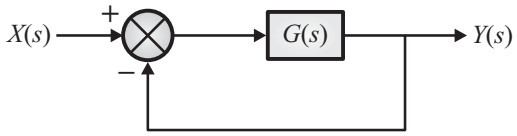
Question 40 (Control System)

The unit step response $y(t)$ of a unity feedback system with open loop transfer function $G(s)H(s)=\frac{K}{(s+1)^2(s+2)}$ is shown in the figure. The value of K is _____ (up to 2 decimal places).



Ans. **8**

Sol. **Given :** $G(s)=\dfrac{K}{(s+1)^2(s+2)}$



[Unit feedback system]

CLTF is given by,

$$\frac{Y(s)}{X(s)}=\frac{G(s)H(s)}{1+G(s)H(s)}=\frac{G(s)}{1+G(s)}$$

$$\frac{Y(s)}{X(s)}=\frac{\dfrac{K}{(s+1)^2(s+2)}}{1+\dfrac{K}{(s+1)^2(s+2)}}$$

$$\frac{Y(s)}{X(s)}=\frac{K}{(s+1)^2(s+2)+K}$$

$$Y(s)=\frac{1}{s}\times\frac{K}{(s+1)^2(s+2)+K}$$

From final value theorem,

$$y(\infty)=\lim_{s\to 0}sY(s)=0.8$$

[From time response shown in the figure steady state value in time domain is 0.8]

$$\frac{K}{2+K}=0.8$$

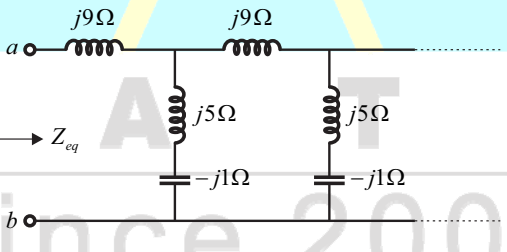
$$K=1.6+0.8K$$

$$K=8$$

Hence, the value of K is **8.**

Question 41 **(Network Theory)**

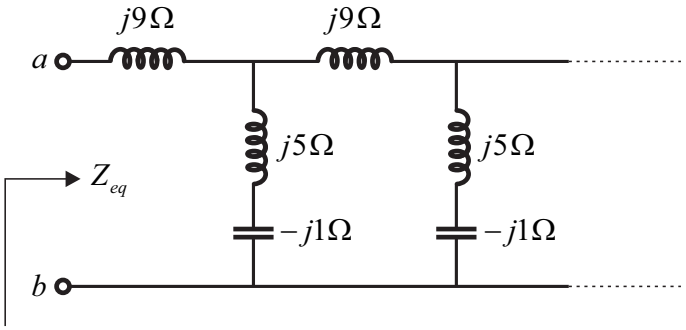
The equivalent impedance Z_{eq} for the infinite ladder circuit shown in the figure is



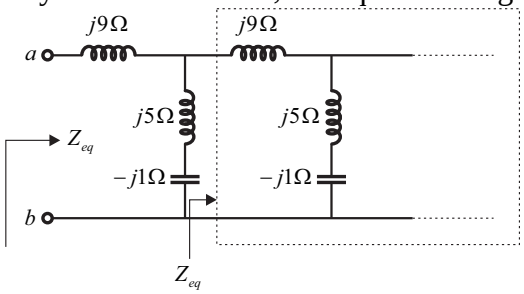
(A) $j12\ \Omega$ (B) $-j12\ \Omega$ (C) $j13\ \Omega$ (D) $13\ \Omega$

Ans. **(A)**

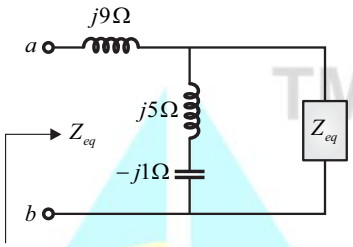
Sol. **Given :** The circuit is given below,



The given network consists only reactive element, the equivalent figure can be represented as,



The above circuit can be re-drawn as shown below,



The equivalent impedance (Z_{eq}) is given as

$$Z_{eq} = \frac{j4 \times Z_{eq}}{j4 + Z_{eq}} + j9$$

$$Z_{eq} = \frac{(j9)Z_{eq} + (j4)Z_{eq} - 36}{Z_{eq} + j4}$$

$$Z_{eq}^2 - (j9)Z_{eq} + 36 = 0$$

$$Z_{eq}^2 - (j12) + (j3)Z_{eq} + 36 = 0$$

$$(Z_{eq} - j12) + (Z_{eq} + j3) = 0$$

$Z_{eq} = j12$ [$Z_{eq} = -j3$ is neglected as the whole circuit is a inductive nature]

Hence, the correct option is (A).

Question 42 (Control System)

The number of roots of the polynomial, $s^7 + s^6 + 7s^5 + 14s^4 + 31s^3 + 73s^2 + 25s + 200$, in the open left half of the complex plane is

(A) 3 (B) 4 (C) 5 (D) 6

Ans. (A)

Sol. **Given :** Characteristic equation, $s^7 + s^6 + 7s^5 + 14s^4 + 31s^3 + 73s^2 + 25s + 200$.

The R-H table is given by,

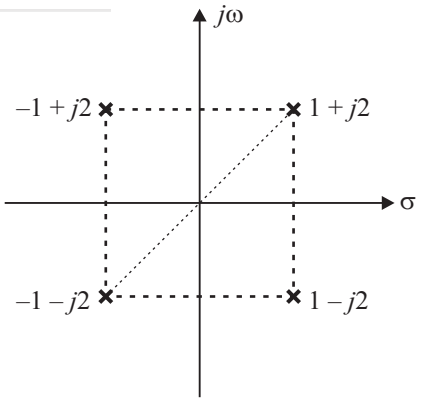
s^7	1	7	31	25
s^6	1	14	73	200
s^5	– 7	– 42	– 175	0
s^4	8	48	200	0
s^3	32	96	0	
s^2	24	200	0	
s^1	– 170.67	0		
s^0	200			

From the above table number of sign change in the first column is 4. So, the number of left hand pole are $7-4=3$.

$$8s^4+48s^2+200=0$$
$$s^2=x$$
$$8x^2+48x+200=0$$
$$x^2+6x+25=0$$
$$x=-3\pm j4$$
$$s^2=-3\pm j4$$
$$s=\sqrt{-3\pm j4}$$
$$s=\sqrt{-3+j4},\ s=\sqrt{-3-j4}$$
$$x+jy=\sqrt{-3+j4}$$
$$(x+jy)^2=-3+j4$$
$$x^2-y^2+j2xy=-3+j4$$
$$x^2-y^2=-3$$
$$2xy=4$$
$$xy=2$$
$$(x^2+y^2)^2=(x^2-y^2)^2+4x^2y^2$$
$$(x^2+y^2)^2=(-3)^2+4\times4=9+16=25$$
$$x^2+y^2=5$$
$$x^2-y^2=-3$$
$$x^2+y^2=5$$
$$2x^2=2$$
$$x^2=1$$
$$x\pm1$$
$$x=+1,\ x=-1$$
$$y=2,\ y=-2$$
$$xy=+\text{ve}$$
$$s=1+j2$$
$$s=-1-j2$$

Now,

$$x+jy=\sqrt{-3-j4}$$
$$x^2-y^2+j2xy=-3-j4$$
$$x^2-y^2=-3$$
$$2xy=-4\Rightarrow xy=-2$$
$$(x^2+y^2)^2=(x^2-y^2)^2+4x^2y^2=(-3)^2+4(-2)^2=25$$
$$x^2+y^2=5$$



$$x^2 - y^2 = -3$$
$$2x^2 = 2$$
$$x^2 = 1$$
$$x = \pm 1$$
$$2xy = -4$$
$$xy = -2$$
$$x = +1,\ x = -1$$
$$y = -2,\ y = 2$$
$$s = 1 - j2 = -1 + j2$$

Hence, the correct option is (A).

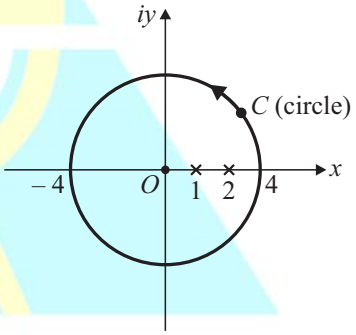
Question 43 (Engineering Mathematics)

If C is a circle $|z| = 4$ and $f(z) = \dfrac{z^2}{(z^2 - 3z + 2)^2}$, then $\oint_C f(z)\,dz$ is

(A) 1 (B) 0 (C) –1 (D) –2

Ans. (B)

Sol. **Given :** $I = \oint \dfrac{z^2}{(z-1)^2 (z-2)^2} dz;\ |z| = 4$



Finding roots of denominator,

$$(z-1)^2 (z-2)^2 = 0$$
$$z = 1, 1, 2, 2$$

[Multiple poles]

Cauchy integral formula for multiple poles

$$\oint \frac{f(z)}{(z-a)^n} dz = \frac{2\pi i}{(n-1)!} \frac{d^{n-1}}{dz^{n-1}} [f(z)]_{z=0}$$

As both the poles are inside the closed curve, hence

$$\oint_C \frac{z^2}{(z-1)^2 (z-2)^2} dz = \oint \frac{z^2/(z-1)^2}{(z-2)^2} + \oint \frac{z^2/(z-2)^2}{(z-1)^2} dz$$

$$\oint_C \frac{z^2}{(z-1)^2 (z-2)^2} dz = \frac{2\pi i}{(z-1)1} \left[\frac{d}{dz} \frac{z^2}{(z-1)^2} + \frac{d}{dz} \frac{z^2}{(z-2)^2} \right]$$

$$\oint_C \frac{z^2}{(z-1)^2 (z-2)^2} dz = 2\pi i \left[\frac{(z-1)^2 \cdot 2z - z^2 2(z-1)}{(z-1)^4} + \frac{(z-2)^2 \cdot 2z - z^2 2(z-2)}{(z-2)^4} \right]$$

$$\oint_C \frac{z^2}{(z-1)^2 (z-2)^2} dz = 2\pi i \left(\frac{4-8}{1} + \frac{2+2}{1} \right) = 2\pi i (-4+4) = 0$$

Hence, the correct option is (B).

Question 44 **(Electromagnetic Field)**

The capacitance of an air-filled parallel-plate capacitor is 60 pF. When a dielectric slab whose thickness is half the distance between the plates, is placed on one of the plates covering it entirely, the capacitance becomes 86 pF. Neglecting the fringing effects, the relative permittivity of the dielectric is _____ (up to 2 decimal places).

Ans. **2.53**

Sol. **Given :** Capacitance of an air-filled parallel plate capacitor,

$$C_0 = \frac{\varepsilon_0 A}{d} = 60\,\text{pF} \qquad \ldots(i)$$

Overall capacitance, $C_{eq} = 86\,\text{pF}$

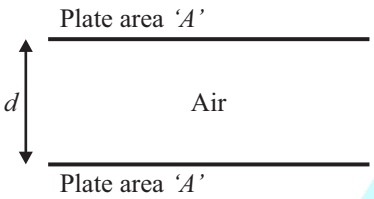


Fig. 1

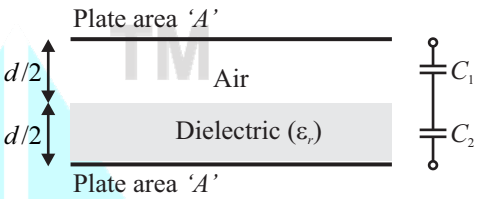


Fig. 2

From fig. 2, after filling with dielectric it has become series combination of two capacitances overall capacitance for series combination is given by,

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = 86\,\text{pF} \qquad \ldots(ii)$$

$$C_1 = \frac{\varepsilon_0 A}{d/2} \text{ and } C_2 = \frac{\varepsilon_0 \varepsilon_r A}{d/2}$$

From equation (ii),

$$C_{eq} = \frac{\frac{\varepsilon_0 A}{d/2} \times \frac{\varepsilon_0 \varepsilon_r A}{d/2}}{\frac{\varepsilon_0 A}{d/2} + \frac{\varepsilon_0 \varepsilon_r A}{d/2}} = \frac{\varepsilon_0 A}{d/2} \frac{(\varepsilon_r)}{(1+\varepsilon_r)}$$

$$86 = 120\left(\frac{\varepsilon_r}{1+\varepsilon_r}\right)$$

$$86(1+\varepsilon_r) = 120\,\varepsilon_r$$

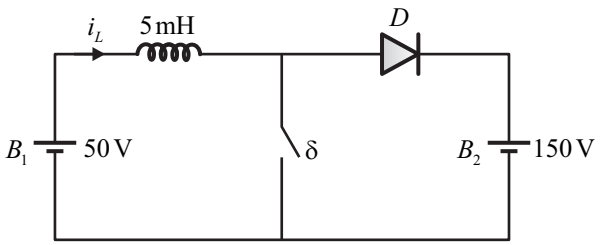
$$86 = 34\,\varepsilon_r$$

$$\varepsilon_r = 2.529$$

Hence, the relative permittivity of the dielectric is **2.53.**

Question 45 **(Power Electronics)**

A dc to dc converter shown in the figure is charging a battery bank, B_2 whose voltage is constant at 150 V. B_1 is another battery bank whose voltage is constant at 50 V. The value of the inductor. L is 5 mH and the ideal switch. S is operated with a switching frequency of 5 kHz with a duty ratio of 0.4. Once the circuit has attained steady state and assuming the diode D to be ideal, the power transferred from B_1 to B_2 (in Watt) is _____ (up to 2 decimal places).



Ans. **12**

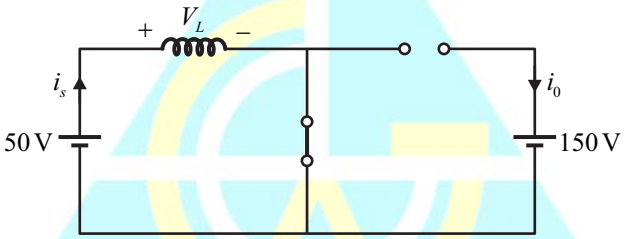
Sol. The given circuit is a step up chopper

$$T_{ON} = DT = 0.4 \times \frac{1}{f} = 0.4 \times \frac{1}{5 \times 10^3} = 0.08\,\text{msec}$$

$$T_{OFF} = T - T_{ON} = 0.2 - 0.08 = 0.12\,\text{msec}$$

Device working status :

Case I : When switch is ON



$$V_L = L\frac{di}{dt} = 50$$

$$\frac{di}{dt} = \frac{50}{L} = \frac{50}{5 \times 10^{-3}}$$

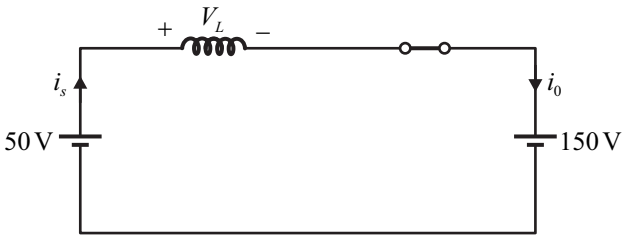
$$\frac{\Delta I}{DT} = \frac{50}{5 \times 10^{-3}}$$

$$\Delta I = \frac{50}{5 \times 10^{-3}} \times DT = \frac{50}{5 \times 10^{-3}} \times 0.4 \times \frac{1}{5 \times 10^3}$$

$$\Delta I = 0.8\,\text{A}$$

Case II : We have to check, whether we have continuous on discontinuous conduction. Hence we find $T_{OFF\,new}$.

During $T_{OFF} \rightarrow$ Switch is open and diode is ON.



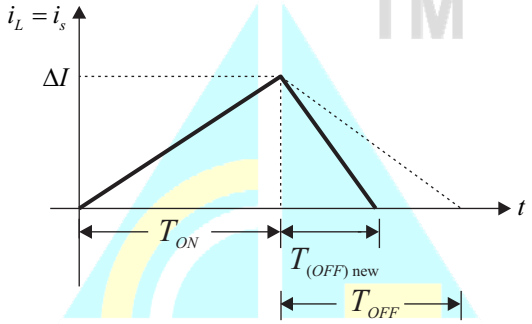
$$V_L = L\frac{di}{dt} = (-100)$$

$$\frac{\Delta I}{T_{OFF}} = \left(-\frac{100}{L}\right)$$

$$T_{OFF} = \frac{-L \times \Delta I_L}{100} = \frac{-5\times10^{-3}\times0.8}{100}$$

$$T_{OFF} = 4\times10^{-5} = 0.04 \text{ msec}$$

As $T_{(OFF)\text{new}} < T_{OFF}$. Hence conduction will be discontinuous.

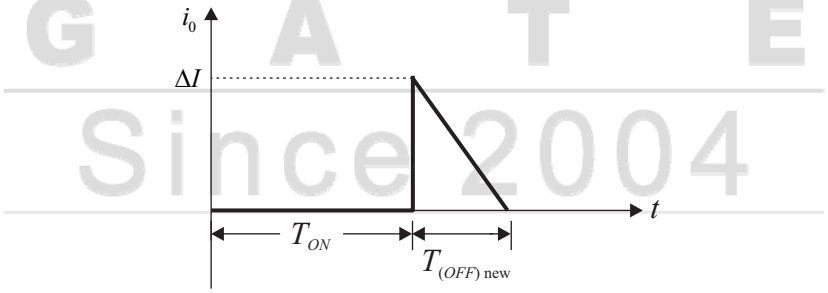


Now, $$I_L \text{ or } I_{s(avg)} = \frac{1}{2}\left[\frac{\Delta I \times T_{ON} + \Delta I \times T_{(OFF)\text{new}}}{T}\right] = \frac{1}{2}\times0.8[10^{-3}\times0.12\times f]$$

$$I_{s(avg)} = 0.4\times0.12\times10^3\times5\times10^3 = (0.24)\text{ A}$$

Hence, $$P_{avg} = V_s I_{s(avg)} = 12\text{ W}$$

Calculation of output power :



$$I_{0(avg)} = \frac{1}{2}\times\frac{\Delta I \times T_{(OFF)\text{new}}}{T}$$

$$I_{0(avg)} = \frac{1}{2}\times0.8\times0.04\times10^{-3}\times5\times10^3$$

$$I_{0(avg)} = 0.4\times0.04\times5 = 0.08\text{ A}$$

Hence, $P_0 = I_0 V_0 = 0.08\times150 = 12$ W

Question 46 (Digital Electronics)

Digital input signals *A, B, C* with A as the MSB and *C* as the LSB are used to realize the Boolean function $F = m_0 + m_2 + m_3 + m_5 + m_7$, where m_i denotes the i^{th} minterm. In addition. *F* has a don't care for m_1. The simplified expression for *F* is given by

(A) $\bar{A}\bar{C} + \bar{B}C + AC$ (B) $\bar{A} + C$ (C) $\bar{C} + A$ (D) $\bar{A}C + BC + A\bar{C}$

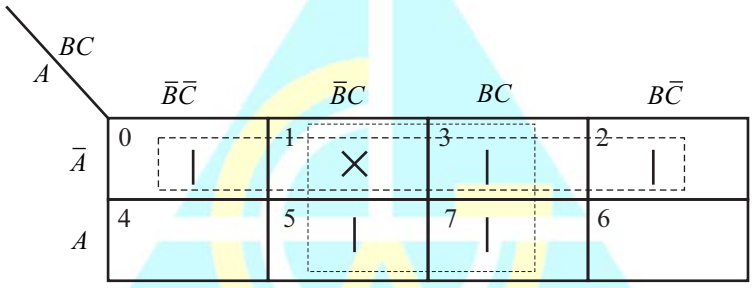
Ans. (B)

Sol.

$$F = m_0 + m_2 + m_3 + m_5 + m_7$$

Also, F has don't care at m_1,

$$F(A,B,C) = \Sigma m(0,2,3,5,7) + \Sigma\phi(1)$$



$$F_1 = \Sigma m(0,1,2,3) = \bar{A}$$

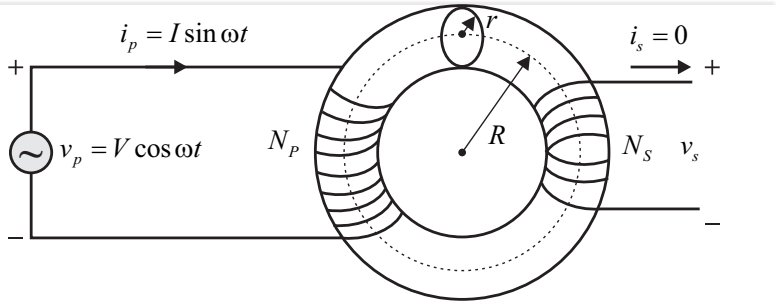
$$F_2 = \Sigma m(1,3,5,7) = C$$

$$F = F_1 + F_2 = \bar{A} + C$$

Hence, the correct option is (B).

Question 47 (Electrical Machine)

A transformer with toroidal core of permeability μ is shown in the figure. Assuming uniform flux density across the circular core cross - section of radius of $r << R$, and neglecting any leakage flux, the best estimate for the mean radius *R* is



(A) $\dfrac{\mu V r^2 N_P^2 \omega}{I}$ (B) $\dfrac{\mu I r^2 N_P N_S \omega}{V}$ (C) $\dfrac{\mu V r^2 N_P^2 \omega}{2I}$ (D) $\dfrac{\mu I r^2 N_P^2 \omega}{2V}$

Ans. **(D)**

Sol. **Given :**

Transformer with toroidal core of permeability μ.

From the given figure,

r = equivalent radius of core

$A = \pi r^2$ = cross sectional area of core

R = mean radius of core

$l = 2\pi R$ = mean length of core

The applied input voltage at primary,

$$v_p = N_P \frac{d\phi}{dt} = N_P \frac{d}{dt}\left(\frac{N_P i_P}{R_L}\right) \qquad [R_L = \text{Reluctance}]$$

$$v_P = \frac{N_P^2}{R_L}\frac{d}{dt}(I\sin\omega t) = \frac{N_P^2}{R_L} \times \omega I \cos\omega t = V\cos\omega t$$

Where, $$V = \frac{N_P^2 \omega I}{R_L} = \frac{N_P^2 \omega I}{\frac{l}{\mu A}} = \frac{N_P^2 \omega I \mu A}{l} = \frac{N_P^2 \omega I \mu \pi r^2}{2\pi R}$$

Hence, $$R = \frac{N_P^2 \omega I \mu r^2}{2V}$$

Hence, the correct option is (D).

Question 48 (Engineering Mathematics)

Let $f(x) = 3x^3 - 7x^2 + 5x + 6$. The maximum value of $f(x)$ over the interval [0, 2] is _____ (upto one decimal place)

Ans. **12**

Sol. **Given :** $f(x) = 3x^3 - 7x^2 + 5x + 6$

To find the maximum value of the function $f(x)$, $f'(x) = 0$ and $f''(x) < 0$

$$f'(x) = 9x^2 - 14x + 5 = 0$$

$$x = 1, \frac{5}{9}$$

$$f''(x) = 18x - 14$$

$$f''(x)\big|_{x=1} = 18 \times 1 - 14 = 4 > 0$$

$$f''(x)\big|_{x=\frac{5}{9}} = 18 \times \frac{5}{9} - 14 = -4 < 0$$

x	$\frac{5}{9}$	0	2
$f(x)$	7.131	6	12

$$f(x)_{\max} = 12$$

Hence, the function $f(x)$ has the maximum value of **12**.

Question 49 (Electrical Machine)

A 3-phase 900 kVA, 3 kV/$\sqrt{3}$ kV (Δ / Y). 50 Hz transformer has primary (high voltage side) resistance per phase of $0.3\,\Omega$ and secondary (low voltage side) resistance per phase of $0.02\,\Omega$. Iron loss of the transformer is 100 kW. The full load % efficiency of the transformer operated at unity power factor is _____ (up to 2 decimal places).

Ans. 97.36

Sol. **Given :** Three phase transformer

(i) kVA = 900

(ii) Primary line voltage $= V_l(\Delta) = 3$ kV

(iii) Secondary line voltage $= V_l(\text{Y}) = \sqrt{3}$ kV

(iv) Primary resistance per phase $= R_{ph}(\Delta) = 0.3\ \Omega$

(v) Secondary resistance per phase $= R_{ph}(\text{Y}) = 0.02\ \Omega$

(vi) Iron loss $(P_i) = 10$ kW

The percentage efficiency of the transformer is given by,

$$\%\eta = \frac{x(\text{kVA})\cos\phi}{x(\text{kVA})\cos\phi + P_i + x^2 P_{cufl}} \times 100 \qquad \ldots. \text{(i)}$$

At full load, fraction of loading $(x) = 1$

$$P_{cufl} = 3I^2_{ph\Delta} R_{ph}(\Delta) + 3I^2_{phY} R_{ph}(\text{Y}) \qquad \ldots. \text{(ii)}$$

Where, $I_{ph\Delta} = \frac{900}{3 \times V_{l\Delta}} = \frac{900}{3 \times 3} = 100\,\text{A}$ and $I_{phY} = \frac{900}{\sqrt{3} V_{lY}} = \frac{900}{\sqrt{3} \times \sqrt{3}} = 300\,\text{A}$

From equation (ii),

$$P_{cufl} = 3 \times 100^2 \times 0.3 + 3 \times 300^2 \times 0.02 = 14.4\,\text{kW}$$

Hence, percentage efficiency is given by,

$$\%\eta = \frac{1 \times 900 \times 1}{1 \times 900 \times 1 + 10 + 14.4} \times 100$$

$$\%\eta = 97.36$$

Hence, the full load efficiency of the transformer is **97.36 %.**

Question 50 (Signals & Systems)

The Fourier transform of a continuous-time signal $x(t)$ is given by $X(\omega) = \frac{1}{(10 + j\omega)^2}$, $-\infty < \omega < \infty$, where $j = \sqrt{-1}$ and ω denotes frequency. Then the value of $|\ln x(t)|$ at $t = 1$ is _____ (up to 1 decimal place). (ln denotes the logarithm to base e).

Ans. **10**

Sol. We know that

$$e^{-at}u(t) \xleftrightarrow{FT} \frac{1}{a+j\omega}$$

Put $a = 10$

$$e^{-10t}u(t) \longleftrightarrow \frac{1}{10+j\omega}$$

Apply multiplication by t property [frequency differentiation property]

i.e., $tx(t) \longleftrightarrow j\frac{d}{d\omega}X(\omega)$

$$te^{-10t}u(t) \longleftrightarrow j\frac{d}{d\omega}\left[\frac{1}{10+j\omega}\right]$$

$$te^{-10t}u(t) \longleftrightarrow \left[\frac{1}{(10+j\omega)^2}\right]$$

$$|\ln x(t)|_{t=1} = |\ln\{te^{-10t}u(t)\}|_{t=1}$$

$$= \left|\ln(t) + \ln\left[e^{-10t}\right] + \ln\left[u(t)\right]\right|_{t=1}$$

$$= \left|\ln(1) + (-10t) + \ln\left[u(t)\right]\right|$$

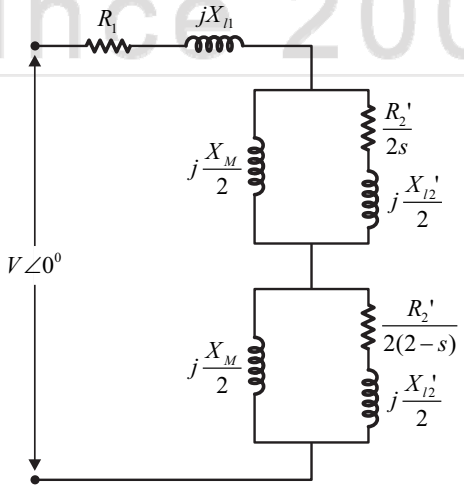
$$= \left|0 + (-10\times 1) + \ln(1)\right|$$

$$= \left|0 - 10 + 0\right|$$

$$= \left|-10\right| = 10$$

Question 51 **(Electrical Machine)**

The equivalent circuit of a single phase induction motor is shown in the figure, where the parameters are $R_1 = R_2' = X_{l1} = X_{l2}' = 12\ \Omega$, $X_m = 240\ \Omega$ and s is the slip. At no-load, the motor speed can be approximated to be the synchronous speed. The no-load lagging power factor of the motor is _____(up to 3 decimal places).



Ans. **0.106**

Sol. **Given :** Single phase induction motor,

A single phase induction motor having,

$$R_1 = R_2 = 12\ \Omega$$

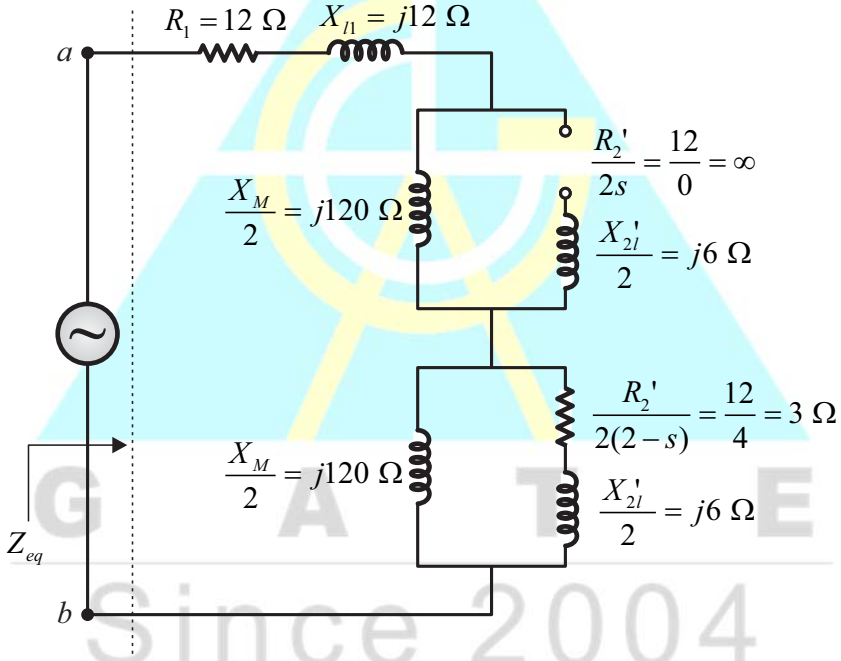
$$X_m = 240\ \Omega$$

$$X_2 = X_1 = 12\ \Omega$$

As the single phase induction motor is running approximately at synchronous speed (N_s), hence

$$\text{Slip } (s) = \frac{N_s - N_r}{N_s} = \frac{N_s - N_s}{N_s} = 0 \qquad [\text{as } N_r = N_s]$$

The equivalent circuit under this condition is shown below,



The equivalent impedance,

$$Z_{eq} = \left[\frac{(3 + j6) \times j120}{3 + j6 + j120}\right] + j120 + j12 + 12$$

$$Z_{eq} = 14.7195 + 137.779\,j = 138.563\angle 83.9019^0$$

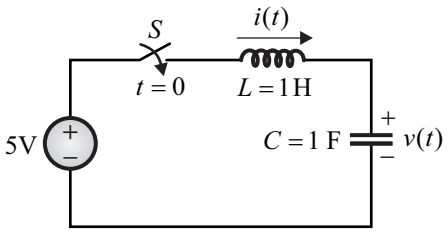
The input power factor is given by,

$$(\cos\phi) = \cos 83.9019^0 = 0.106 \text{ lagging}.$$

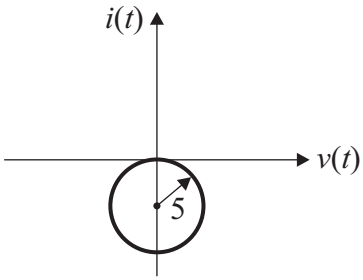
Hence, the no load lagging power factor of the motor is **0.106.**

Question 52 (Network Theory)

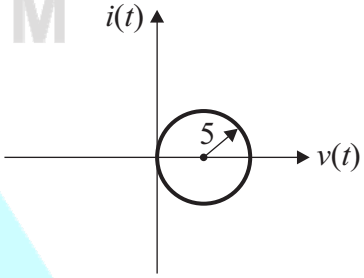
A DC voltage source is connected to a series L-C circuit by turning on the switch S at time $t = 0$ as shown in the figure. Assume $i(0) = 0,\ v(0) = 0$. Which one of the following circular loci represents the plot of $i(t)$ versus $v(t)$?



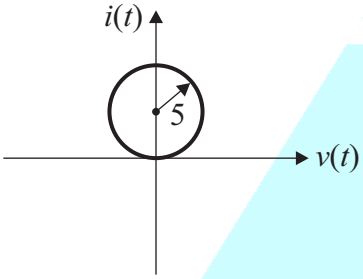
(A)



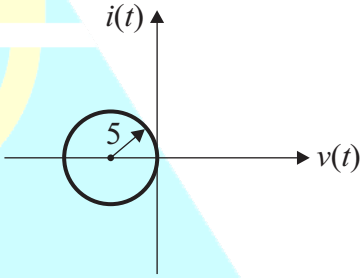
(B)



(C)

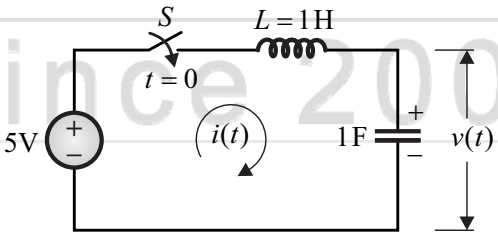


(D)

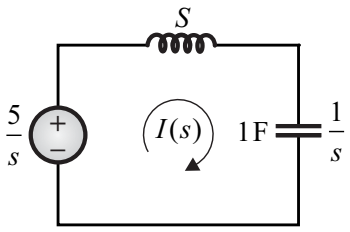


Ans. (B)

Sol. **Given :** The circuit with $i(0) = 0 = v(0) = 0$



The equivalent circuit is represented as,

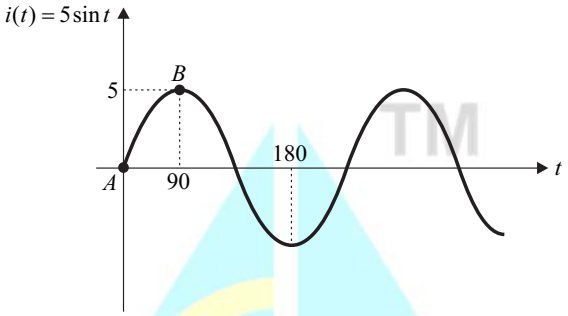


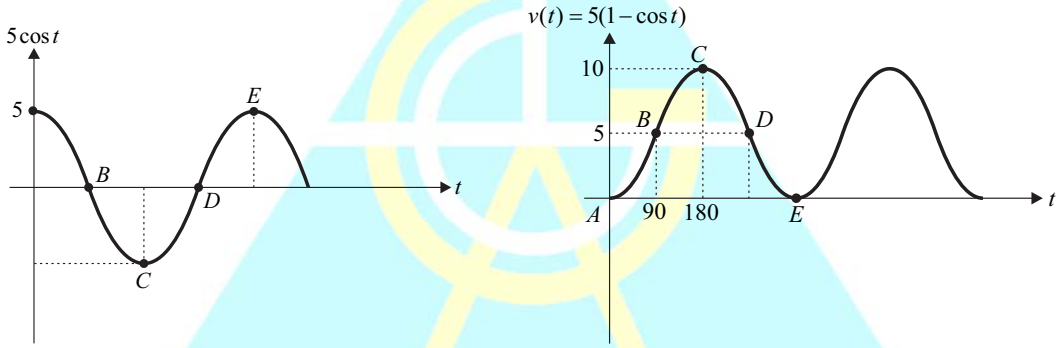
$$I(s)=\frac{\frac{5}{s}}{s+\frac{1}{s}}=\frac{5}{s^2+1}$$

$$i(t)=5\sin t$$

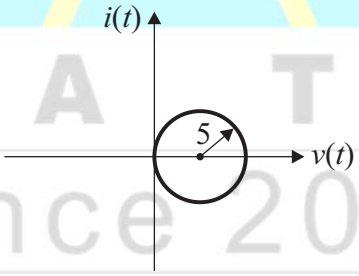
$$V(t)=\frac{1}{C}\int_0^t i(t)\,dt=\frac{1}{1}\int_0^t 5\sin t$$

$$V(t)=5(1-\cos t)$$





The circular loci of $i(t)$ is given by,



Hence, the correct option is (B).

Question 53 (Control System)

Consider a system governed by the following equations

$$\frac{dx_1(t)}{dt}=x_2(t)-x_1(t)$$

$$\frac{dx_2(t)}{dt}=x_1(t)-x_2(t)$$

The initial conditions are such that $x_1(0)<x_2(0)<\infty$. Let $x_{1f}=\lim_{t\to\infty}x_1(t)$ and $x_{2f}=\lim_{t\to\infty}x_2(t)$. Which one of the following is true?

(A) $x_{1f}<x_{2f}<\infty$ (B) $x_{2f}<x_{1f}<\infty$ (C) $x_{1f}=x_{2f}<\infty$ (D) $x_{1f}=x_{2f}=\infty$

Ans. **(C)**

Sol. Converting to state model

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}-1 & 1\\ 1 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

$$A=\begin{bmatrix}-1 & 1\\ 1 & -1\end{bmatrix}$$

$$(sI-A)=\begin{bmatrix}s+1 & -1\\ 1 & s+1\end{bmatrix}$$

$$(sI-A)^{-1}=\begin{bmatrix}s+1 & -1\\ 1 & s+1\end{bmatrix}\frac{1}{s^2+2s}$$

$$(sI-A)^{-1}=\begin{bmatrix}\frac{s+1}{s(s+2)} & \frac{1}{s(s+2)}\\ \frac{1}{s(s+2)} & \frac{s+1}{s(s+2)}\end{bmatrix}=\begin{bmatrix}\frac{1}{2s}+\frac{1}{2(s+2)} & \frac{1}{2s}-\frac{1}{2(s+2)}\\ \frac{1}{2s}-\frac{1}{2(s+2)} & \frac{1}{2s}+\frac{1}{2(s+2)}\end{bmatrix}$$

$$\phi(t)=\frac{1}{2}\begin{bmatrix}1+e^{-2t} & 1-e^{-2t}\\ 1-e^{-2t} & 1+e^{-2t}\end{bmatrix}$$

$$x(t)=\phi(t)x(0)=\frac{1}{2}\begin{bmatrix}1+e^{-2t} & 1-e^{-2t}\\ 1-e^{-2t} & 1+e^{-2t}\end{bmatrix}\begin{bmatrix}x_1(0)\\ x_2(0)\end{bmatrix}=\frac{1}{2}\begin{bmatrix}x_1(0)+x_2(0)+e^{-2t}[x_1(0)-x_2(0)]\\ x_1(0)+x_2(0)+e^{-2t}[x_2(0)-x_1(0)]\end{bmatrix}$$

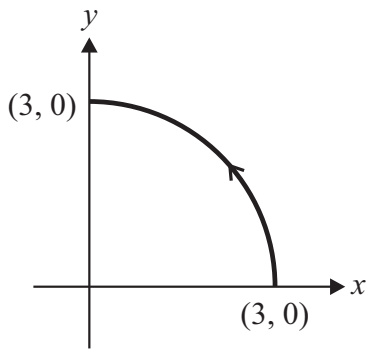
$$x_f=\lim_{t\to\infty}x(t)=\frac{1}{2}\begin{bmatrix}x_1(0)+x_2(0)\\ x_1(0)+x_2(0)\end{bmatrix}$$

Hence, $x_{1f}=x_{2f}<\infty$

Hence the correct option is (C).

Question 54 **(Engineering Mathematics)**

As shown in the figure, C is the arc from the point (3, 0) to the point (0, 3) on the circle $x^2+y^2=9$. The value of the integral $\int_C (y^2+2xy)\,dx+(x^2+2xy)\,dy$ is _____ (up to 2 decimal places).



Ans. **0**

Sol. **Given :** $x^2 + y^2 = 9$ this equation is given for circle in first quadrant and from figure we know centre (0, 0) and radius of 3.

For closed line integral we applies green's theorem.

Green's theorem,

$$\oint_C \phi dx + \psi dy = \iint_S \left(\frac{\partial \psi}{\partial x} - \frac{\partial \phi}{\partial y} \right) dx\, dy \qquad \text{.....(i)}$$

Here, $\phi = y^2 + 2xy$ (given) and $\psi = x^2 + 2xy$ (given)

So, $\frac{\partial \psi}{\partial x} = 2x + 2y$ and $\frac{\partial \phi}{\partial y} = 2y + 2x$

Put the above values in equation (i), we get

$$\oint_C \phi dx + \psi dy = \iint_S (2x + 2y) - (2x + 2y)\, dx\, dy$$

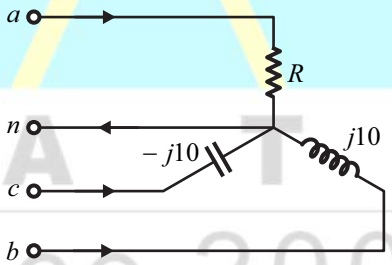
$$\oint_C \phi dx + \psi dy = 0$$

Hence the value of integral is **0.**

Question 55 **(Network Theory)**

A three-phase load is connected to a three-phase balanced supply as shown in the figure.

If $V_{an} = 100\angle 0^0$ V, $V_{bn} = 100\angle -120^0$ V and $V_{cn} = 100^0 \angle -240^0$ V (angles are considered positive in the anti-clockwise direction), the value of R for zero current in the neutral wire is _____Ω (up to 2 decimal places).

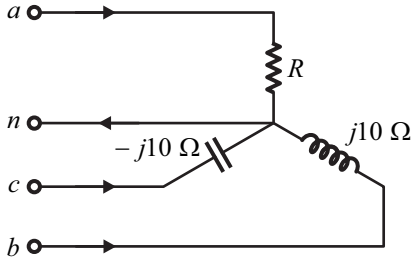


Ans. **5.77**

Sol. **Given :** $V_{an} = 100\angle 0^0$

$V_{bn} = 100\angle -120^0$

$V_{cn} = 100^0 \angle -240^0$



$$I_a + I_b + I_c = I_n = 0$$

$$\frac{100\angle 0}{R} + \frac{100\angle -120}{j10} + \frac{100\angle -240}{-j10} = 0$$

$$\frac{100\angle 0}{R} + 10\angle -210 + 10\angle -150 = 0$$

$$\frac{100\angle 0}{R} = 8.66 - 5j + 8.66 - 5j = 17.32 - 10j \quad \text{.... (i)}$$

Equating the real part of the equation (i),

$$\frac{100}{R} = 17.32$$

$$R = \frac{100}{17.32} = 5.773\ \Omega$$

Hence, the value of R is **5.773 Ω.**

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Answer Key :

General Aptitude									
1.	C	2.	A	3.	D	4.	A	5.	D
6.	C	7.	C	8.	(*) 4/11	9.	C	10.	C
Technical Section									
1.	D	2.	17.39	3.	0.5	4.	0.5	5.	3500
6.	A	7.	D	8.	0.67	9.	C	10.	A
11.	B	12.	D	13.	B	14.	A	15.	B
16.	7	17.	C	18.	A	19.	73.52	20.	C
21.	5.5	22.	600	23.	B	24.	D	25.	A
26.	A	27.	A	28.	90	29.	A	30.	C
31.	25	32.	825	33.	2.86	34.	50	35.	B
36.	10	37.	1	38.	D	39.	C	40.	8
41.	A	42.	A	43.	B	44.	2.53	45.	12
46.	B	47.	D	48.	12	49.	97.36	50.	10
51.	0.106	52.	B	53.	C	54.	0	55.	5.77

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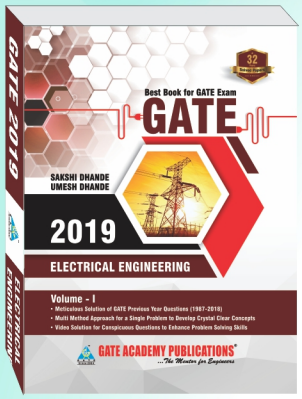

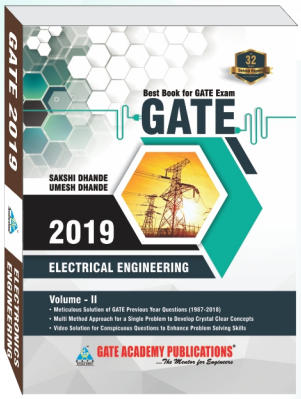

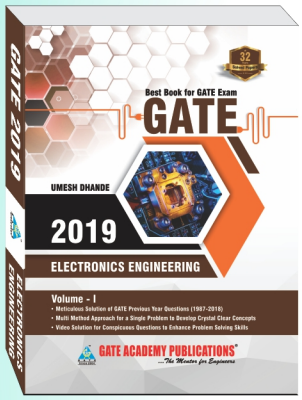

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